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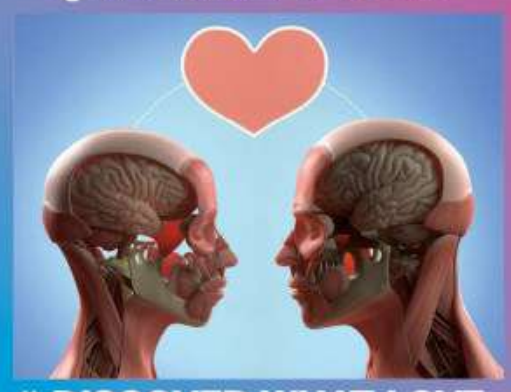

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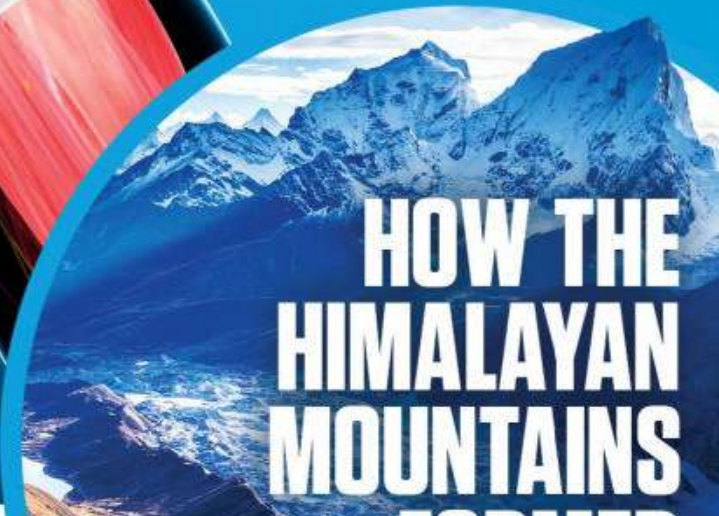

HOW THE HIMALAYAN MOUNTAINS FORMED

FUTURE

ISSUE 137

+ SUPER-STRONG METALS WHO WAS TYPHOID MARY? SHOTGUN ANATOMY

© Mr. Bean

and BRILLIANT*

The beloved ~~oddball~~ Mr Bean famously drives a 1976 British Leyland Mini 1000 on his adventures. The 'Citron' lime green coloured car is fitted with numerous ~~bizarre~~ GENIUS security features including a bolted latch and padlock on the driver's door and a removable steering wheel.

← Not on this tiny model!

* NB: This product description has been skilfully corrected by Mr Bean (of London)

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ISSUE **137**

WELCOME

The magazine that feeds minds!

"The heart has to pump between three and four times more blood during a race"

Inside the body of a runner, page 18

Meet the team...

Nikole
Production Editor
The European Space Agency's Solar Orbiter is on its way to study our Sun and its poles. Learn more about its mission on page 64.

Scott
Staff Writer
What's inside the unopened tomb of the First Emperor of China and why hasn't anyone looked inside? Find out on page 28.

Baljeet
Research Editor
How does our brain feel love, and what changes in our body are caused by this powerful emotion? Explore the science of love on page 36.

Duncan
Senior Art Editor
Turn to page 56 to see how advanced self-managing robots are helping humans in different ways and making our lives better.

Ailsa
Staff Writer
The Himalayas are home to the world's tallest mountains and lots of rare animals. Discover how this land came to be on page 44.

Long-distance running is hard… we can all agree on that. Just watch a marathon and you'll see people straining and sweating their way through. You might be surprised at the toll it takes on the human body though – and the benefits, despite the short-term damage that's done to the heart and lungs. In this issue's special feature, we explore what the benefits of training for a marathon are, the impact that race day has on your body at every mile, what muscles are employed with each stride and why certain running recovery techniques are so effective. It's a fascinating read whether you're a keen runner or just interested in human biology.

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Ben Editor

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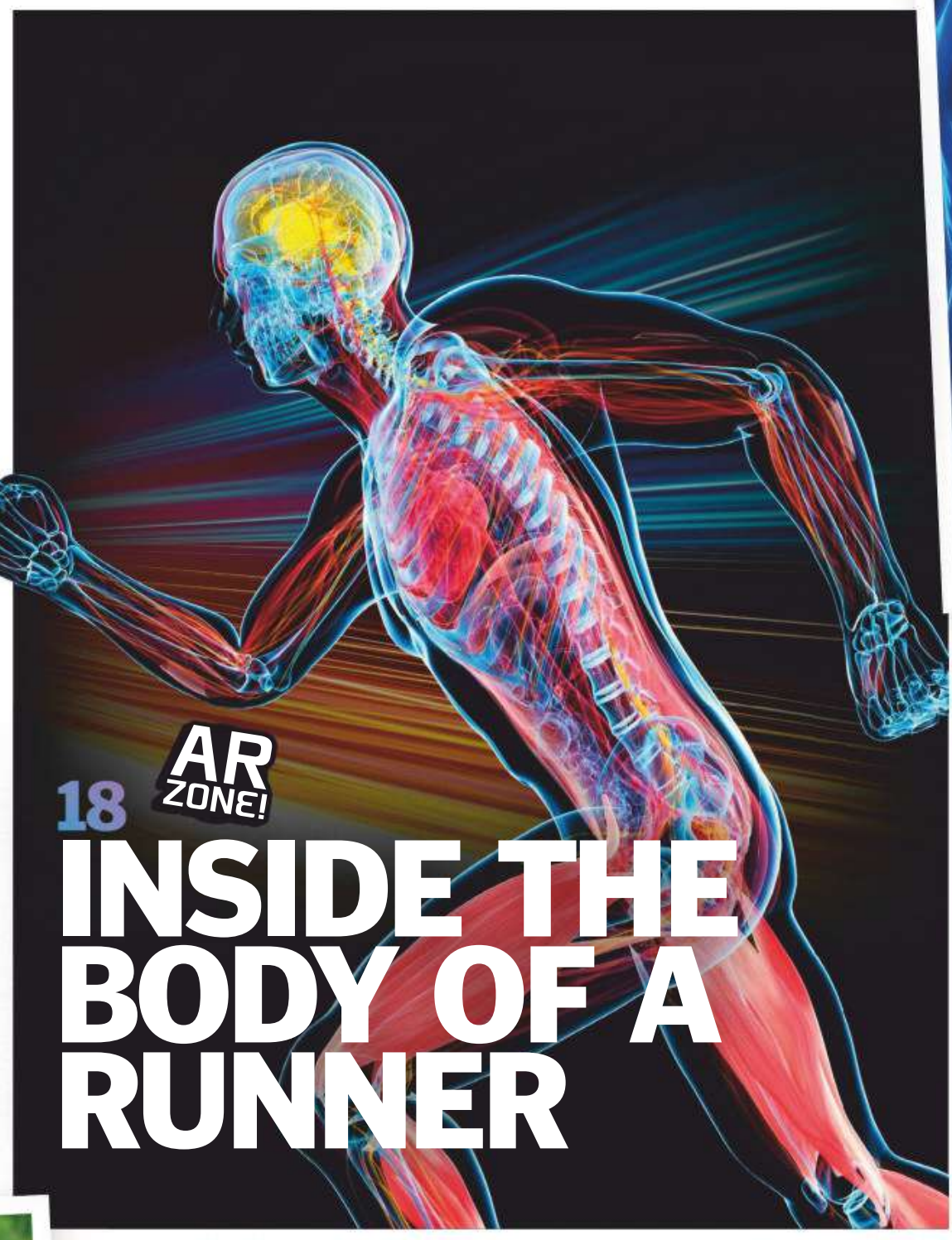

AR ZONE!

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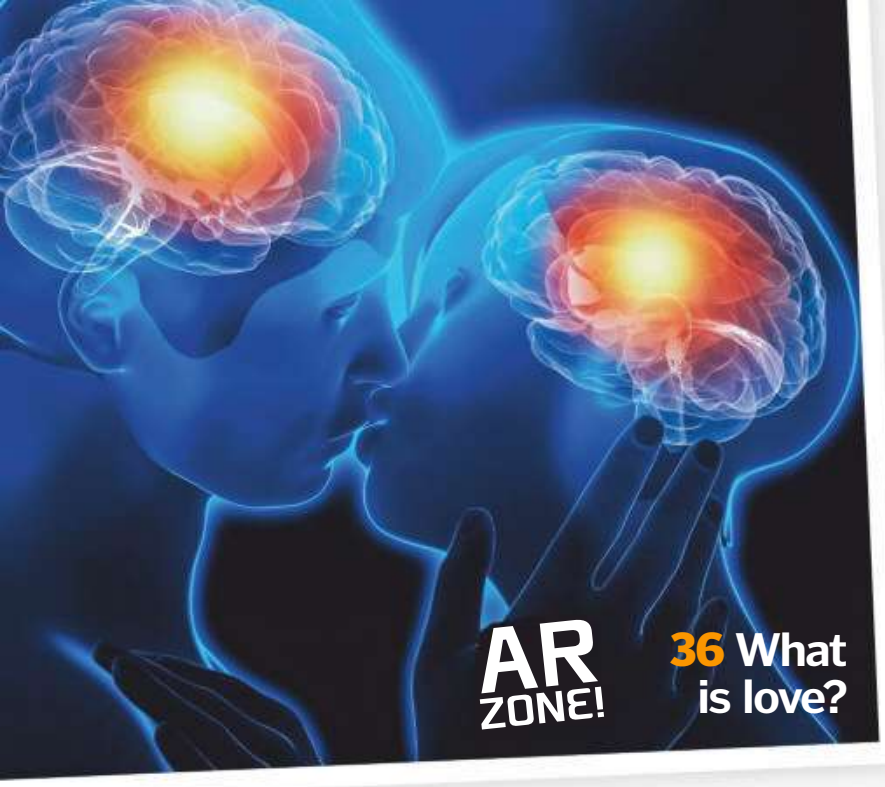
MEET THIS ISSUE'S EXPERTS...

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.



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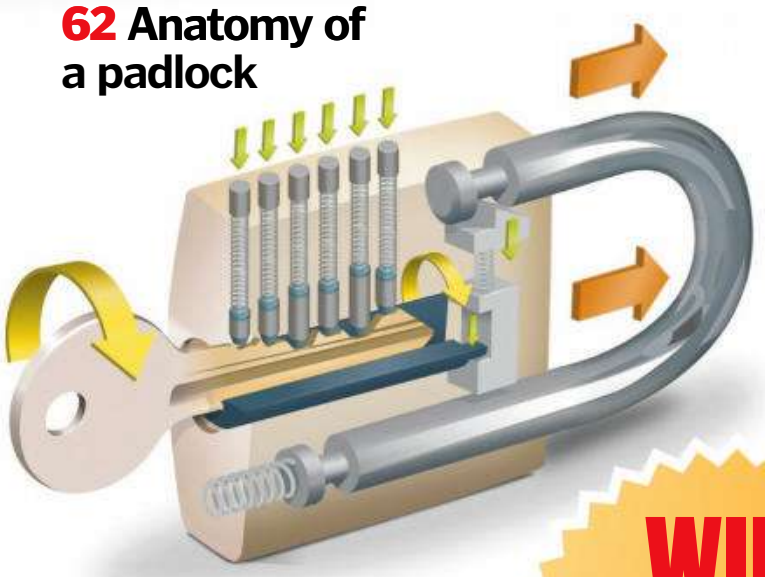

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Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now also working towards her PhD in computational evolution.

Jack Parsons
A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but also loves to write about projects with much grander ambitions.

Mike Jennings
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport.

MIGHTY MANDIBLES

Scurrying beneath the undergrowth, these beasty beetles can grow up to around eight centimetres long. Male stag beetles (*Lucanus cervus*) are most recognisable by their impressively oversized mandibles, reminiscent of a male deer (stag), hence the name. However, the female members of the species, like the one pictured here, are much smaller: around three to four centimetres long. This stag beetle was captured using light microscopy by Viktor Sykora for The Royal Photographic Society's 2019 science photography competition. You can find out more about this year's entries at **rps.org/spoty**.

© Viktor Sykora

STORMY JUPITER

Jupiter is well known as one of the Solar System's most volatile planets. As a gas giant, Jupiter is mostly made up of hydrogen and helium, which surrounds a dense rock and ice core. Filling its gaseous atmosphere are bountiful amounts of hydrogen, helium, ammonia and methane, swept into massive storms by the planet's aggressive winds that reach up to 539 kilometres per hour. This stormy scene of Jupiter's northern hemisphere was captured by NASA's Juno on its 20th pass of the planet. Orbiting between 8,600 and 18,600 kilometres above the giant storms, Juno snapped the swirling, high-altitude, bright-white clouds, commonly referred to as 'pop-up' clouds.

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With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.

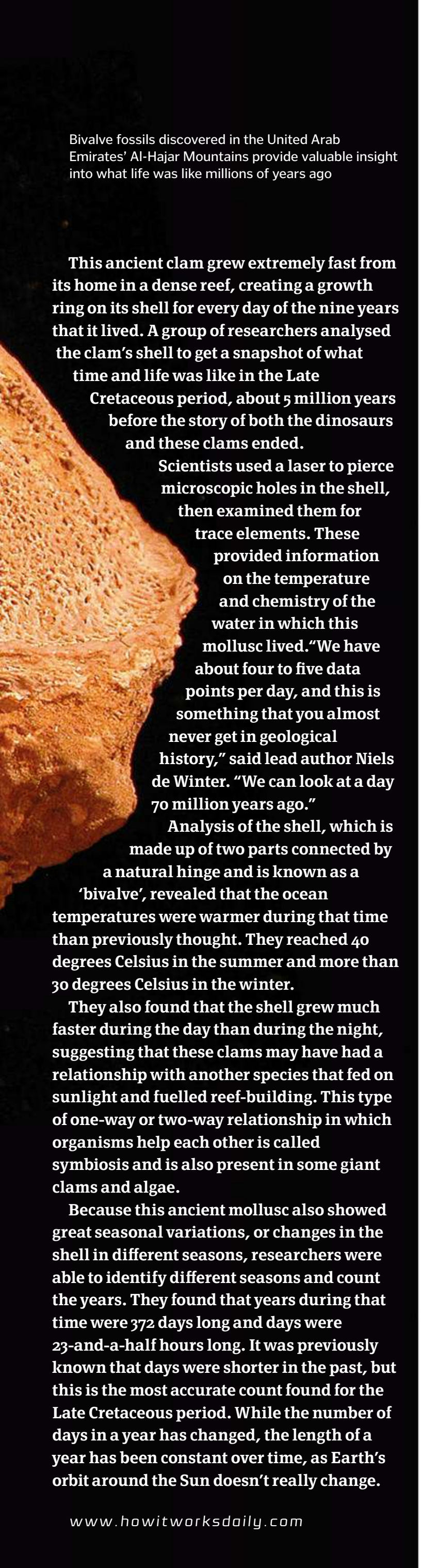
Source: Wiki/ Wilson44691

HISTORY

Ancient shell reveals shorter days for dinosaurs

Words by **Yasemin Saplakoglu**

When dinosaurs still left fresh footprints on the mud, our planet twirled around faster than it does today. Chronicled in the rings of an ancient timekeeper is a story of days half an hour shorter and years a week longer than they are today. That ancient timekeeper is an extinct rudist clam, one of a group of molluscs that once dominated the role that corals fill today in building reefs. The clam belonged to the species *Torreites sanchezi* and lived 70 million years ago in a shallow tropical seabed which is now dry land in the mountains of Oman in the Middle East.



Bivalve fossils discovered in the United Arab Emirates' Al-Hajar Mountains provide valuable insight into what life was like millions of years ago

This ancient clam grew extremely fast from its home in a dense reef, creating a growth ring on its shell for every day of the nine years that it lived. A group of researchers analysed the clam's shell to get a snapshot of what time and life was like in the Late Cretaceous period, about 5 million years before the story of both the dinosaurs and these clams ended.

Scientists used a laser to pierce microscopic holes in the shell, then examined them for trace elements. These provided information on the temperature and chemistry of the water in which this mollusc lived. "We have about four to five data points per day, and this is something that you almost never get in geological history," said lead author Niels de Winter. "We can look at a day 70 million years ago."

Analysis of the shell, which is made up of two parts connected by a natural hinge and is known as a 'bivalve', revealed that the ocean temperatures were warmer during that time than previously thought. They reached 40 degrees Celsius in the summer and more than 30 degrees Celsius in the winter.

They also found that the shell grew much faster during the day than during the night, suggesting that these clams may have had a relationship with another species that fed on sunlight and fuelled reef-building. This type of one-way or two-way relationship in which organisms help each other is called symbiosis and is also present in some giant clams and algae.

Because this ancient mollusc also showed great seasonal variations, or changes in the shell in different seasons, researchers were able to identify different seasons and count the years. They found that years during that time were 372 days long and days were 23-and-a-half hours long. It was previously known that days were shorter in the past, but this is the most accurate count found for the Late Cretaceous period. While the number of days in a year has changed, the length of a year has been constant over time, as Earth's orbit around the Sun doesn't really change.

www.howitworksdaily.com

© Andrew Turner/University of Plymouth

An assortment of weathered LEGO bricks pulled from the ocean

PLANET EARTH

LEGO bricks can survive 1,300 years in the sea

Words by **Brandon Specktor**

The ocean around the UK is strewn with LEGO. Some of them were flushed there; one UK insurance company estimates that children flushed some 2.5 million LEGO pieces down the loo between 2006 and 2016. Other bricks arrived there in 1997 when a wave slammed a cargo ship and dumped 62 containers – one containing nearly 4.8 million pieces of LEGO – overboard. Some bricks still wash onto the shore, but most sink to the bottom, and there they will remain for a thousand years or more.

In a recent study, researchers compared 50 castaway LEGO bricks trawled from the coastlines of southwest England with 50 matching bricks that never left their boxes. Using X-rays and other analytic tools to measure how much of the marine bricks had weathered away, the team determined that a single LEGO brick can survive in the ocean for anywhere from 100 to 1,300 years before totally degrading.

Because most LEGO bricks are stamped with serial numbers, it was relatively easy for the researchers to date the sea-weathered bricks and then compare them with identical unweathered bricks obtained from local collections. Many of the underwater LEGO dated to the 1970s and 1980s, the researchers said, and had suffered noticeable decay.

"The pieces we tested had smoothed and discoloured, with some of the structures having fractured and fragmented, suggesting that as well as pieces remaining intact, they might also break down into microplastics," said lead study author Andrew Turner.

Some pieces had lost up to 40 per cent of their original mass while at sea; others lost only three per cent. Ultimately, the researchers said, the type and thickness of the plastic used in a given brick determined how quickly it decayed, but it's likely that the average LEGO could remain intact in the sea for hundreds of years.

According to the researchers, these findings reinforce the message that people should be more thoughtful about how they dispose of used household items. Please don't chuck your toys into the toilet or the sea.

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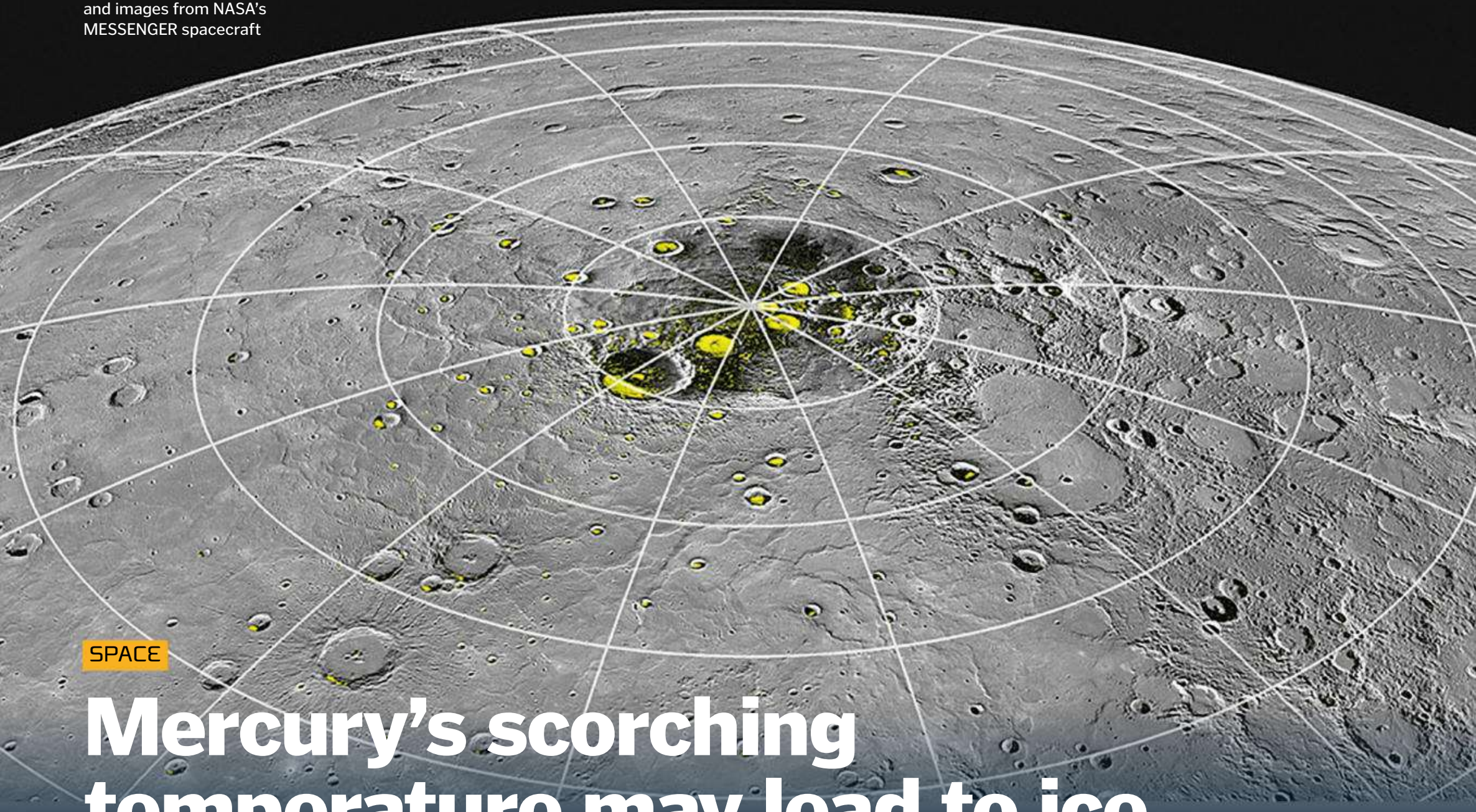
Despite Mercury's extreme heat there is permanent ice at the planet's poles, according to data and images from NASA's MESSENGER spacecraft



SPACE

Mercury's scorching temperature may lead to ice

Words by **Elizabeth Howell**

Could Mercury's close orbit around the Sun help the planet generate ice? It sounds like a paradox, but new analysis of the planet's surface chemistry suggests that heat-generated ice may indeed be the case.

Even though daytime temperatures on Mercury soar to 430 degrees Celsius, ice can occur in craters sheltered from the Sun. There the surface is exposed to cold space at about minus 200 degrees Celsius.

We've known about this ice for almost a decade thanks to observations from NASA's now-defunct MESSENGER (Mercury Surface, Space Environment, Geochemistry and Ranging) spacecraft. But the explanation for how some of the ice got there, chemically speaking, remains under investigation. A new study shows how water can collect on the surface even amid these extremely hot temperatures.

"This is not some strange, out-of-left-field idea. The basic chemical mechanism has been observed dozens of times in studies since the late 1960s," said lead author Brant Jones. "But that was on well-defined surfaces. Applying that chemistry to complicated surfaces like those on a planet is groundbreaking research."

The minerals on Mercury's surface contain groups of bonded oxygen and hydrogen atoms known as hydroxyls. Protons from the solar wind – the constant stream of charged particles from the Sun – are common on the planet's surface, since there is not enough of a magnetic field to repel the particles.

This study's model suggests that the magnetic field can cause protons – positively charged subatomic particles – to migrate across Mercury, so the protons can then implant themselves in the soil and the hydroxyl groups. The Sun's searing heat energises the hydroxyl groups, causing them to crash into each other. These collisions create water, which is also made from hydrogen and oxygen, just in different proportions, as well as freeing up extra hydrogen that leaves the surface and drifts above Mercury.

"Daytime temperatures on Mercury soar to 430 degrees Celsius"

As for the water molecules, some of them get broken down by sunlight and dissociate into their elemental components. Other water molecules escape from the surface and fly into space. However, a few water molecules escape these fates and instead land on the poles of Mercury, making it into permanently shadowed craters.

And there the molecules can stay, since Mercury has no substantial atmosphere that would further affect the water molecules by conducting heat, for example. While this sounds like a subtle process, over time the water ice would add up.

The model suggests that in 3 million years, Mercury would accumulate nearly 10 trillion kilograms of water ice, which is roughly ten per cent of the observed ice on the planet. Other ice may have arrived from small worlds such as asteroids, comets and meteorites.

© NASA/MESSENGER

HISTORY

Leopard face reconstructed from ancient Egyptian sarcophagus

Words by **Mindy Weisberger**

Excavation of an ancient city of the dead in Aswan, Egypt, recently uncovered pieces of a sarcophagus lid that had been decorated with the colourful face of a leopard. Now, archaeologists have released the first image showing a digital reconstruction of the artwork fragment, found in a necropolis containing 300 tombs and dating back to the seventh century BCE.

In the image, as seen below, most of the big cat's wide-eyed face is visible. When the lid rested on the sarcophagus, the head of the leopard would have aligned with the head of the mummy inside.

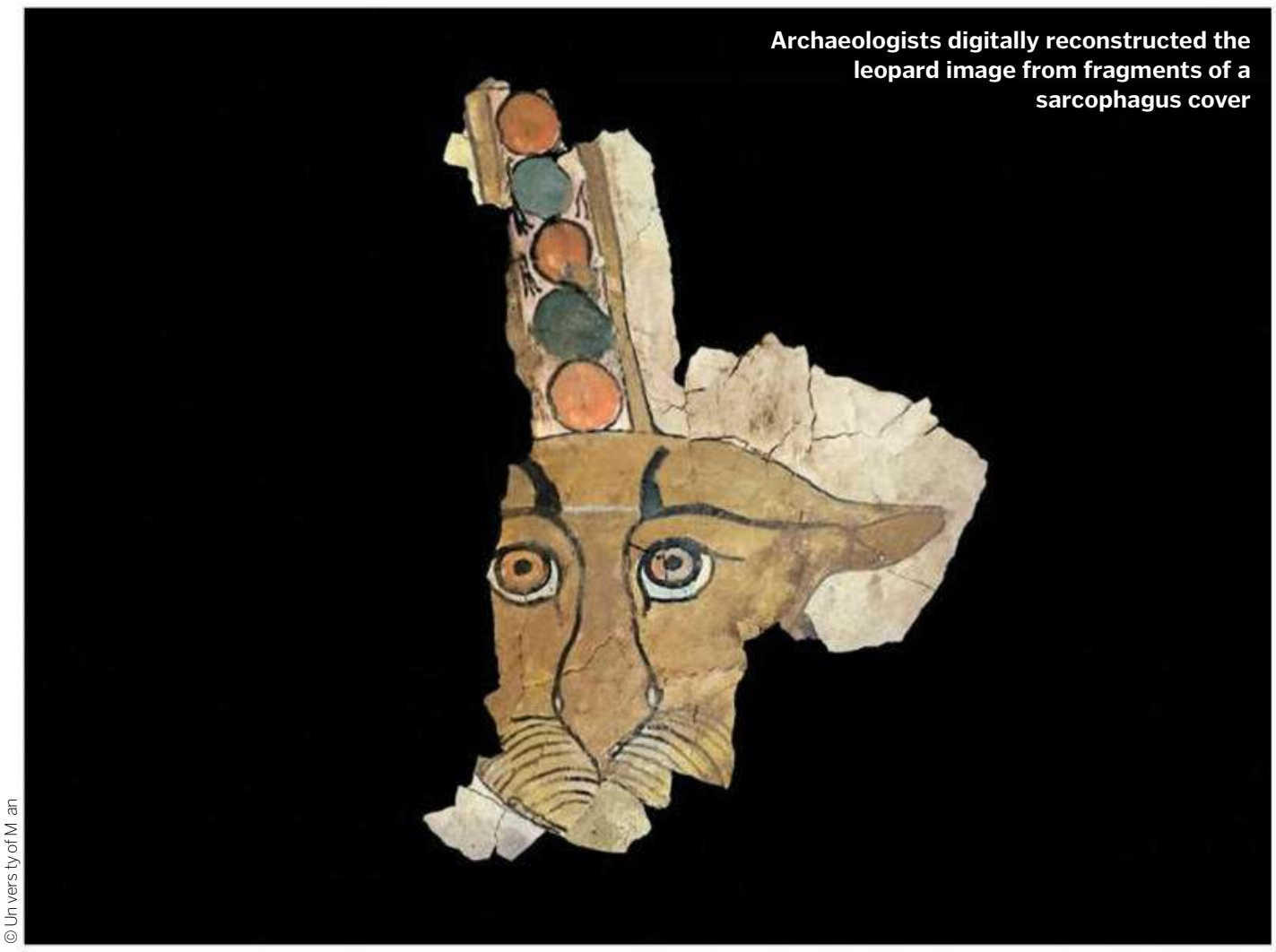
In ancient Egyptian society, leopards represented determination and power; the animal's representation in the tomb was likely intended to strengthen the spirit of the recently deceased for the journey onward to the land of the dead.

The necropolis that housed the leopard sarcophagus was in use for approximately 1,000 years, until the fourth century CE, and the excavation was carried out by an international team of experts with the Egyptian-Italian Mission at West Aswan.

"We made the discovery at the end of January 2019, but just finished the 'virtual' restoration of the fragment," said Patrizia Piacentini, director of the excavation for the Egyptian-Italian Mission at West Aswan.

A nearby tomb held another extraordinary find: a bowl holding plant material that turned out to be pine nuts. Though the nuts were not native to the region, they were known to have been used by chefs in Alexandria, at least according to a collection of Roman cookery recipes called *Apicius* that was compiled in the first century CE.

As for why the pine nuts were left in the necropolis, "We like to imagine that the people buried in the tomb of Aswan loved this rare seed, so much so that their relatives placed a bowl next to the deceased that contained them so that they could feed on them for eternity," said Piacentini.



Archaeologists digitally reconstructed the leopard image from fragments of a sarcophagus cover

© Un vers ty of M an

© Hirola Conservation Program

Two rare white giraffes spotted in Kenya's Ishaqbini Hirola Community Conservancy in 2017

ANIMALS

Poachers kill two of Earth's last white giraffes

Words by **Brandon Specktor**

Rangers at a nature conservancy in Garissa County, Kenya, have discovered the skeletal remains of two rare white giraffes that went missing several months ago. The carcasses belong to a mother and her seven-month-old calf, two of only three white giraffes living in Ishaqbini Hirola Community Conservancy, and appear to have been there for four months. All signs indicate that the animals were killed and butchered by armed poachers.

The poachers have not been identified, and their motive remains unclear. The Kenya Wildlife Service, the main conservation body in Kenya, is investigating the killings. One white giraffe remains in the park, an adult male, and it may be the last in the world.

The white giraffes are not albino, but they do have a condition called leucism, which causes a partial loss of skin pigmentation. Unlike animals with albinism, animals with leucism still produce dark pigment in their soft tissue cells, which is why the giraffes in this family have dark eyes and dark tail hair.

All reticulated giraffes (*Giraffa reticulata*), the species found in the conservancy and throughout northern Kenya, are considered endangered by the International Union for Conservation of Nature. About 15,780 individuals remain in the wild, according to an estimate from the Giraffe Conservation Foundation (GCF). That represents a decline of about 56 per cent from the roughly 36,000 estimated to remain in the wild 30 years ago. The main threats to their survival are loss of habitat due to human activities and poaching.

IN ASSOCIATION WITH LIVESCIENCE

PLANET EARTH

Antarctica and Greenland reach record ice loss

Words by **Brandon Specktor**

Antarctica and Greenland are losing ice six-times faster than in the 1990s. According to the international team of climatologists behind the research, the unprecedented rate of melt has already contributed 1.78 centimetres to global sea level rise in the last three decades, putting the planet on track for the worst-case climate warming scenario laid out in the Intergovernmental Panel on Climate Change's (IPCC) latest report. The dreaded scenario, which predicts a total sea level rise of 60 centimetres by the year 2100, would put 360 million people living in coastal communities at risk of losing their homes, or their lives, to flooding.

"If Antarctica and Greenland continue to track the worst-case climate warming scenario, they will cause an extra 17 centimetres of sea level rise by the end of the century" said study author Andrew Shepherd.

For the new studies, a team of 89 scientists assessed ice loss data from 11 satellites that have been monitoring Antarctica and Greenland since the early 1990s. The data created a detailed picture of how much mass each region's glaciers have lost over the last 30 years, and showed how quickly the remaining ice is flowing into the sea.

The team found that Greenland and Antarctica have lost a combined 6.4 trillion tonnes of ice from 1992 to 2017.

© Getty

The rapid ice loss puts the world right on track for the 'worst-case' climate scenario

Don't worry – asteroid 1998 OR2 won't even come close to hitting us

© Getty

SPACE

'Potentially hazardous' asteroid flies by Earth on 29 April

Words by **Hanneke Weitering**

A large and 'potentially hazardous' asteroid is poised to fly by Earth, but don't worry... it poses no threat to us. Asteroid (52768) 1998 OR2 makes a close approach to Earth on 29 April. The hefty space rock has an estimated diameter of 1.8 to 4.1 kilometres, or about the width of the isle of Manhattan in New York.

While an asteroid that size could cause havoc if it crashed into Earth, prompting some alarmist and misinformed media reports, this asteroid poses no threat.

At its closest approach, which will happen at about 10:56 BST, asteroid 1998 OR2 will be 6.3 million kilometres from Earth. That's more than 16 times the average distance between Earth and the Moon.

NASA has classified asteroid 1998 OR2 as 'potentially hazardous' not because it puts Earth in danger, but because it fulfils certain criteria in the agency's classification scheme. According to NASA, an asteroid qualifies as 'potentially hazardous' if its orbit ever intersects Earth's orbit at a distance less than 7.5 million kilometres, or 0.05 astronomical units, the average distance between Earth and the Sun.

Asteroid 1998 OR2, which orbits the Sun in between the orbits of Earth and Mars, won't fly by Earth again until 18 May 2031, and then it will be farther away, passing about 19 million kilometres from our planet, according to NASA.

Its next two flybys, in 2048 and 2062, will be even farther away. The closest flyby of asteroid 1998 OR2 for the foreseeable future will be on 16 April 2079, when it will be only 1.8 million kilometres away.

NASA and its international partners are actively scanning the skies for potentially hazardous asteroids and studying ways to deflect an Earth-bound asteroid before it strikes and causes a potential widespread disaster. So far about one-third of the 25,000 large asteroids thought to be zooming around in Earth's cosmic neighbourhood have been discovered.

"The space rock has an estimated diameter of 1.8 to 4.1 kilometres"

STRANGE NEWS

Woman's transplanted 'man hands' become lighter and more feminine

Words by **Mindy Weisberger**

A young woman in India who lost both of her hands in a bus accident received limbs from a darker-skinned male donor. Years later, the skin of her transplanted hands has lightened.

After her accident in 2016, 18-year-old Shreya Siddanagowder's arms were amputated below the elbow. In August 2017 she underwent a 13-hour transplant operation performed by a team of 20 surgeons and 16 anesthesiologists.

Her transplanted hands came from a 20-year-old man who died after a bicycle crash. Over the next year and a half, physical therapy improved Siddanagowder's motor control of her arms and hands, which gradually became leaner than they were at the time of the transplant. But there was another unexpected change: the skin on her new limbs, which had been darker because the donor had a darker complexion, became lighter in colour so that they more closely matched Siddanagowder's skin tone.

The doctors who treated Siddanagowder suspect that her body produces less melanin than her donor's did, which could explain the lightening of her new limbs.

Candidates for hand transplants undergo evaluations and consultations that can span months. Experts assess the patient's overall health, conducting blood tests and X-rays and evaluating nerve function in the amputated limbs. Eligible applicants are then placed on a waiting list and are matched with hand donors based on factors such as skin colour, hand size and blood type.

Siddanagowder's visit to the transplant centre at the Amrita Institute of Medical Sciences in Kerala, India, to register for a transplant coincided with a hand donation that matched her blood type. Her surgery was the first double hand transplant performed in Asia, as well as the continent's first intergender limb transplant.

"I am the first female in the world to have male hands," Siddanagowder said in a video shared on Facebook in June 2019 by the MOHAN Foundation, a charitable organisation that supports research in transplantation and organ donation in India.

However, her hands "have feminine features now," Siddanagowder added. One explanation for her hands taking on a more 'feminine' shape could be the muscles adapting to their new host, physiotherapist Ketaki Doke, who worked with Siddanagowder, said. "The nerve begins to send signals – it is called reinnervation – and the muscles function according to body needs," Doke said. "The muscles in her hand may have started adapting to a female body."

Fewer than 100 people have received hand transplants worldwide. Siddanagowder's doctors are monitoring the changes in her hands' skin colour and shape, and they expect to publish the details of her transplant and recovery in a case report, according to Dr Subramania Iyer, head of plastic and reconstructive surgery at the Amrita Institute of Medical Sciences.

However, more evidence will be required to understand what is driving these changes in her transplanted hands, Iyer said.

In 2017, Shreya Siddanagowder underwent Asia's first intergender hand transplant

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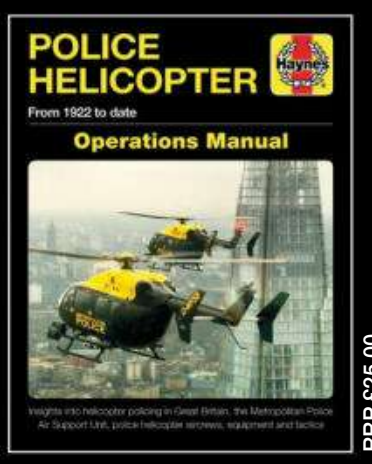

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■ Price: **£375 / $399**
www.theragun.com

Your body's recovery following a workout is imperative to success in reaching your fitness goals. The Theragun G3 delivers deep muscle treatment to promote recovery, increase circulation and relieve muscle tension. Reaching around 16 millimetres into the muscle, the Theragun motor produces 2,400 revolutions per minute to rapidly compress soft tissue for pain relief.

© Theragun

© Polar

Polar Ignite

■ Price: **£174.50 / $229.95**
www.polar.com

Equipped with all the bells and whistles of a smartwatch but with training and exercise in mind, the Polar Ignite provides a personal trainer around your wrist. Offering ready-made exercise plans that match your fitness level and personal goals, Ignite displays your workout in real-time on its display. Along with monitoring heart rate and performance at the gym, Ignite will also monitor your sleep patterns and how long you spend in certain stages of slumber.

Stryd

Price: **£199 / $219**
www.stryd.com

Whether you're training for a marathon, improving your fitness or just running for fun, Stryd is a great tool to help you get the most out of your run. The lightweight sensor attaches to the laces of your running shoes and records analytics such as stride, distance and power. Sending these stats straight to a companion app, Stryd can help you reach your training goals in real-time and even offer performance predictions for a big race.

© Stryd

Melomania 1

Price: **£119.95 / $129.99**
www.cambridgeaudio.com

With up to nine hours playback on a single charge, the Melomania 1 earbuds by Cambridge Audio are a great way to listen to music on the go, at the gym or out for a run. Sweat- and water-resistant, these Bluetooth earbuds can withstand the effects of wet weather if you get caught in the rain on a run. The Melomania 1 earbuds are touch-activated and have a wireless connectivity range of 30 metres.

© Cambridgeaudio

Tonal

Price: **$2,995 (approx. £2,550)**
www.tonal.com

Putting a high-tech twist on the classic home gym, Tonal combines varied gym-style experiences with an integrated digital personal trainer. Tonal has a whole host of coaches and fitness sessions to choose from at the touch of a button. The built-in system calculates your suggested lifting weight up to around 90 kilograms (200 pounds) and makes adjustments based on your performance. If you find yourself struggling, Tonal will spot you and automatically remove the weight.

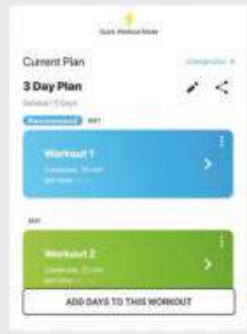
© Tonal

APPS & TOOLS

JEFIT

Developer: **Jefit Inc.**
Price: **Free / Google Play / App Store**

Tailor your exercise schedule with this workout assistant app. Follow set programmes or create your own and JEFIT will monitor your progress.



Adidas Running

Developer: **Runtastic**
Price: **Free / Google Play / App Store**

Keep on top of your running journey with this GPS app. Record your run in real-time, set challenges and receive feedback from its built-in personal trainer.

Nutrition Facts

Developer: **Alexey Korobov**
Price: **Free / Google Play**

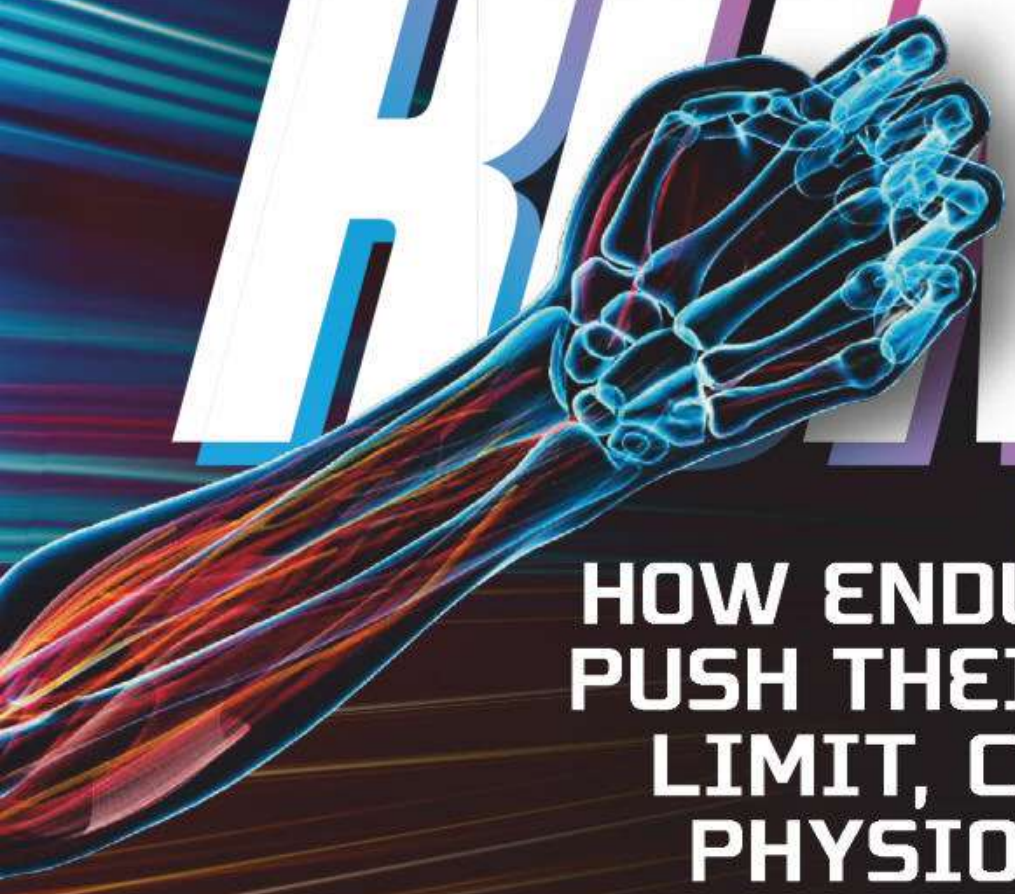
Knowledge is key when it comes to what we eat and staying healthy. This app lists the nutritional information for more than 8,700 products.

Zwift

Developer: **Zwift Inc.**
Price: **Free / Google Play / App Store**

Combining the fun of video games and focus of fitness training, this virtual app puts you into the digital race with others around the world in real-time.

INSIDE THE BODY OF A RUNNER



Words by **Laura Mears**

HOW ENDURANCE RUNNERS PUSH THEIR BODIES TO THE LIMIT, CHANGING THEIR PHYSIOLOGY FOREVER

A marathon is one of the toughest endurance running events on the planet, but race day is just a tiny part of the challenge. On average it takes a runner four-and-a-half hours to complete the 42.2-kilometre (26.2 mile) course, but before that they must endure months of training. During this period, runners average 80 kilometres a week or more, fundamentally changing the fabric of their bodies.

A marathon run drains thousands of calories, and the first major shift in runner physiology is in energy consumption. The body has three energy systems that supply fuel to working muscles, and they all depend on a small molecule called ATP. ATP stands for adenosine triphosphate – a molecule made from an adenosine attached to three phosphate groups. When muscles contract, they snap off one of ATP's phosphate groups,

© Getty

Not everyone who enters is able to finish the tough long-distance run

turning the triphosphate into a diphosphate, called ADP. To carry on exercising, the body needs to reverse the process.

Untrained muscles tend to use fast, wasteful methods to do this as quickly as possible. The simplest uses a molecule called creatine phosphate, which the muscles store for emergencies. Each molecule can instantly donate a phosphate group to turn ADP back into ATP, but supplies only last for about two minutes. When they run out, muscles turn to sugar for support.

Every muscle carries a stock of a carbohydrate called glycogen. It breaks down into glucose, and with further processing the energy tied up inside can replenish spent ADP. The quickest way to do this is without oxygen, turning glucose into lactic acid in a process called anaerobic glycolysis. It might be fast, but anaerobic glycolysis makes the muscles burn and wastes energy. As soon as lactic acid starts to build up, the body begins to fatigue.

One critical aim of marathon training is to teach the muscles to stall anaerobic glycolysis for as long as possible. Endurance runners want their muscles to burn glucose using oxygen – by far the most efficient way to restore ADP to ATP.

> "MUSCLES ONLY STORE ENOUGH SUGAR TO RUN FOR 40 MINUTES"

The point at which muscles switch from using oxygen to making lactic acid is known as the 'lactate threshold', and marathon training pushes it back. The lactate threshold depends on many factors, but one of the most important is VO_2 max – the body's capacity for taking on oxygen during exercise. This increases massively with training – athletes have a VO_2 max up to twice that of inactive people.

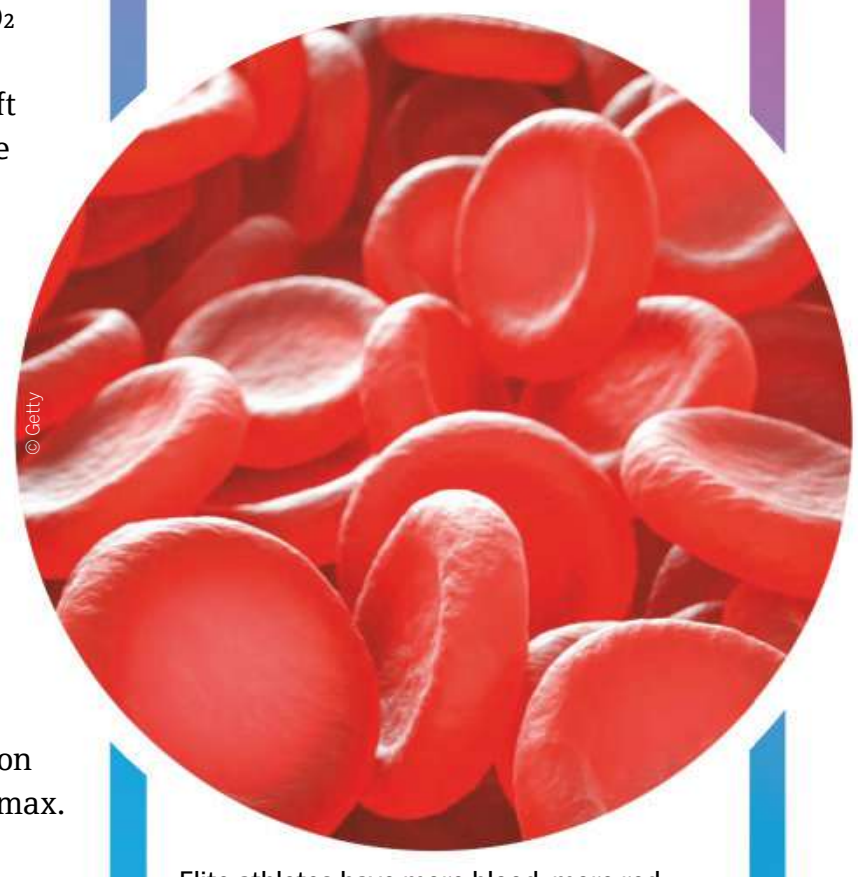
Regular endurance running causes the left side of the heart to thicken and increases the amount of blood in the body. Together these boost the volume of blood forced out with each heartbeat, delivering more oxygen to working muscles. This is critical during a marathon when runners use more than 90 per cent of their maximum cardiac output – the maximum amount their heart can physically pump. Improving the oxygen supply to the muscles helps to keep them burning glucose efficiently for longer. However, to shift the lactate threshold further, the body needs to make even more changes.

In untrained runners, lactic acid production starts to kick in at around 60 per cent of VO_2 max. With training that barrier can shift to 75 per cent. In elite athletes the lactate threshold can be as high as 90 per cent of VO_2 max. Combined with improvements in VO_2 max, this essentially

MAXIMISING MARATHON PERFORMANCE

A deciding factor in a runner's marathon time is their VO_2 max. It's a measure of aerobic capacity describing the maximum volume of oxygen their body can take up.

Oxygen gets from the lungs to the muscles via the bloodstream. The faster and more efficiently it can do this, the more work the muscles can do, and it all comes down to how much oxygen the blood can transport. Experiments on elite athletes have shown that VO_2 max depends on four key factors. The first is red cell mass – how many red blood cells they have. The second is total body haemoglobin – how much red, oxygen-carrying pigment they have in their red blood cells. The third is blood volume – how much total blood they have. And the fourth is stroke volume – how much blood their hearts pump with each beat. More blood, more cells, more haemoglobin and a more powerful heart add up to better performance.



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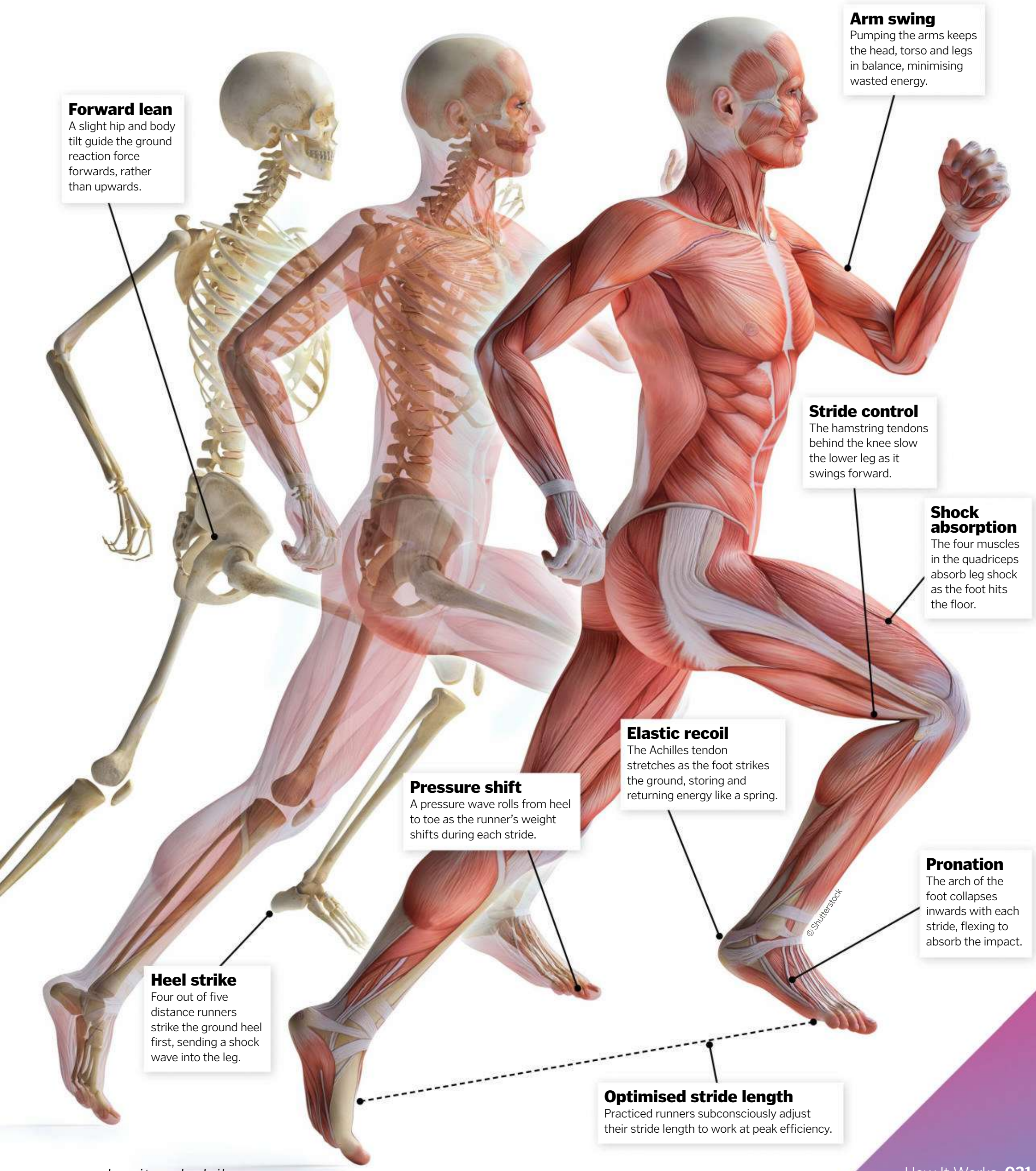
Elite athletes have more blood, more red blood cells and more haemoglobin

Marathon biomechanics

Joints, muscles and tendons come under immense strain as marathon runners pound the pavement



Forward lean
A slight hip and body tilt guide the ground reaction force forwards, rather than upwards.

Arm swing
Pumping the arms keeps the head, torso and legs in balance, minimising wasted energy.

Stride control
The hamstring tendons behind the knee slow the lower leg as it swings forward.

Shock absorption
The four muscles in the quadriceps absorb leg shock as the foot hits the floor.

Elastic recoil
The Achilles tendon stretches as the foot strikes the ground, storing and returning energy like a spring.

Pressure shift
A pressure wave rolls from heel to toe as the runner's weight shifts during each stride.

Pronation
The arch of the foot collapses inwards with each stride, flexing to absorb the impact.

Heel strike
Four out of five distance runners strike the ground heel first, sending a shock wave into the leg.

Optimised stride length
Practiced runners subconsciously adjust their stride length to work at peak efficiency.

© Shutterstock

doubles the amount of power that experienced runners can generate before they reach their lactate threshold.

Part of the power boost granted by endurance training is down to structural changes in the muscles themselves. Every muscle cell is packed with miniature energy factories called mitochondria. In ancient evolutionary history, these factories were once free-living bacteria, and they still have their own DNA. This means that they can divide and grow inside our cells – a phenomenon known as mitochondrial biogenesis. Endurance training vastly increases mitochondria numbers, and when this happens, each cell's capacity for ATP production using oxygen rises.

The effect is especially powerful in type I muscle fibres, also known as 'slow twitch' muscle fibres – the ones responsible for endurance exercise. But it also happens in type II, or 'fast' muscle fibres, which normally prefer to make lactic acid.

Marathon training improves muscle oxygen supply and increases capacity for energy production. But there's one more ingredient needed to restore spent ATP – fuel. The easiest fuel supply for muscles to use is sugar. Each muscle has its own sugar store, and training increases this capacity, allowing runners to pack more carbohydrates into each cell before race day. But even the most elite athletes can't store enough sugar to finish a marathon.

Untrained muscles can hold enough carbohydrate to fuel a 40-minute run. With training this capacity rises to 70 minutes. And there's a glycogen store in the liver which adds another 15 minutes. But even full to the brim, these supplies fall several hours short of the average marathon finishing time.

Taking on extra sugar during the race can help to keep the body topped up. But the stomach doesn't empty as fast as usual when running, especially when food and drink contain lots of sugar. The only way to power a marathon is to find another energy source.

Endurance training unlocks access to the body fat. This fuel reserve contains more than 3,000 kilocalories in every 0.5 kilograms. In the

© Getty

A splash of cold water helps to reduce mid-run body temperature

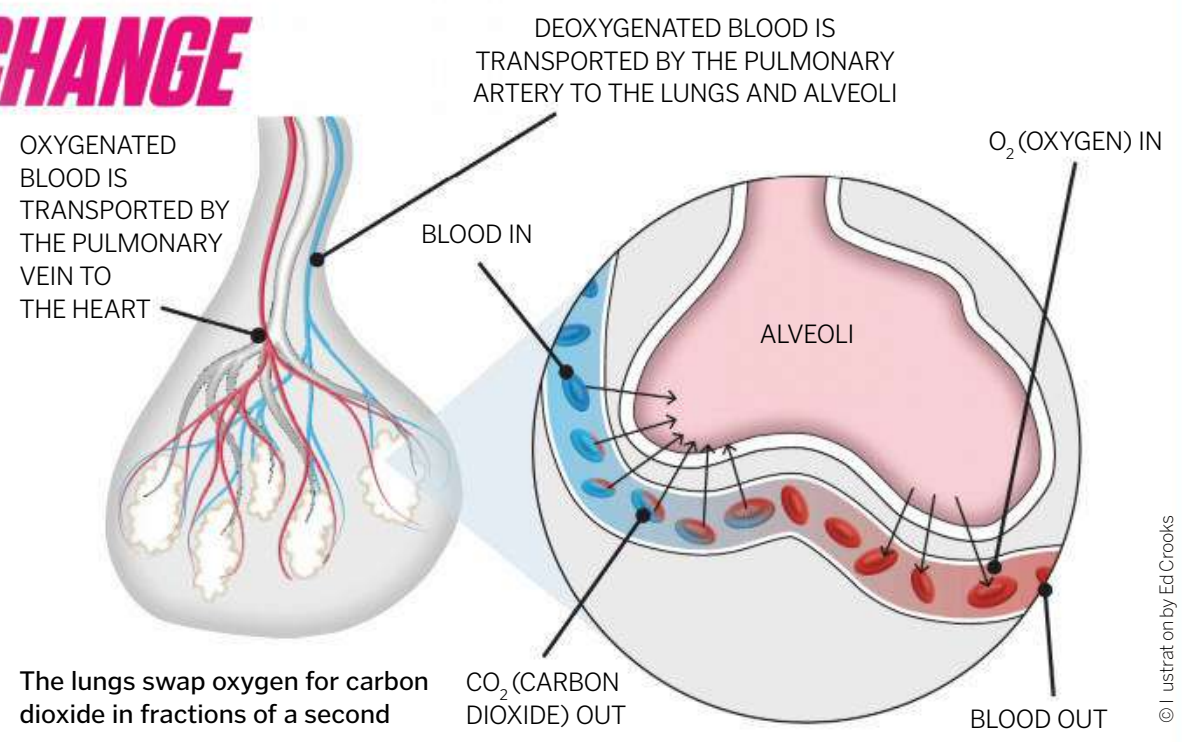
© Getty

Tens of thousands of runners take on the New York City Marathon each year

HIGH-SPEED GAS EXCHANGE

There are 300 million air sacs in the lungs. Known as alveoli, each one is surrounded by a web of ultra-fine blood vessels. Here oxygen from the air passes into red blood cells and carbon dioxide made by the muscles passes into the air.

This exchange is passive – it happens by diffusion – so the only way the body can make gas exchange happen faster is to make the air and the blood move more quickly. It does this by increasing ventilation (airflow) and perfusion (blood flow). During a marathon, breathing rate rises from as few as 12 breaths a minute to as many as 45. The heart beats faster and with more power, increasing its total output by up to six times.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OXYGENATED BLOOD IS TRANSPORTED BY THE PULMONARY VEIN TO THE HEART
BLOOD IN
O_2 (OXYGEN) IN
ALVEOLI
CO_2 (CARBON DIOXIDE) OUT
BLOOD OUT
© Illustration by Adrian Mann

The lungs swap oxygen for carbon dioxide in fractions of a second

GOING THE DISTANCE

1 Stretches at the starting line help to lengthen and prepare the muscles and increase the range of motion of the joints.

2 3 Sweating is minimal and the kidneys are still working at full capacity, so an early toilet stop is sometimes necessary.

4 5 Five miles into the race and runners are working comfortably in their target heart rate zone, around 140 beats per minute.

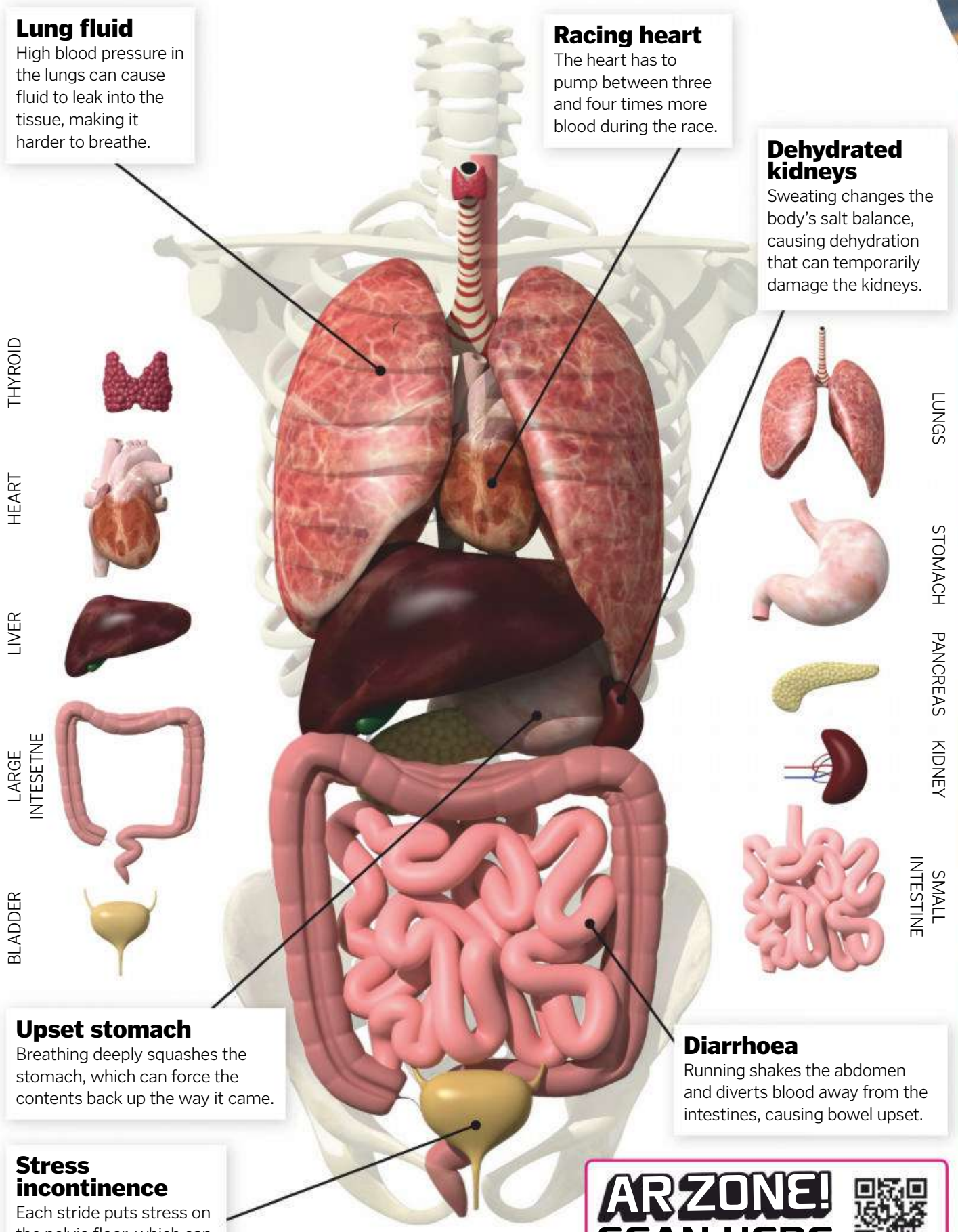
6 7 8 At mile seven it's time to stop at a drink station to replace fluids and electrolytes lost through sweating.

9 10 11 By the ten-mile mark, imbalances in the body's salt and water reserves can start to trigger painful cramps.

12 13

Organs under pressure

Marathon distances push the body's internal organs to their physiological limits



Lung fluid
High blood pressure in the lungs can cause fluid to leak into the tissue, making it harder to breathe.

Racing heart
The heart has to pump between three and four times more blood during the race.

Dehydrated kidneys
Sweating changes the body's salt balance, causing dehydration that can temporarily damage the kidneys.

Upset stomach
Breathing deeply squashes the stomach, which can force the contents back up the way it came.

Diarrhoea
Running shakes the abdomen and diverts blood away from the intestines, causing bowel upset.

Stress incontinence
Each stride puts stress on the pelvic floor, which can cause the bladder to leak.

AR ZONE! SCAN HERE

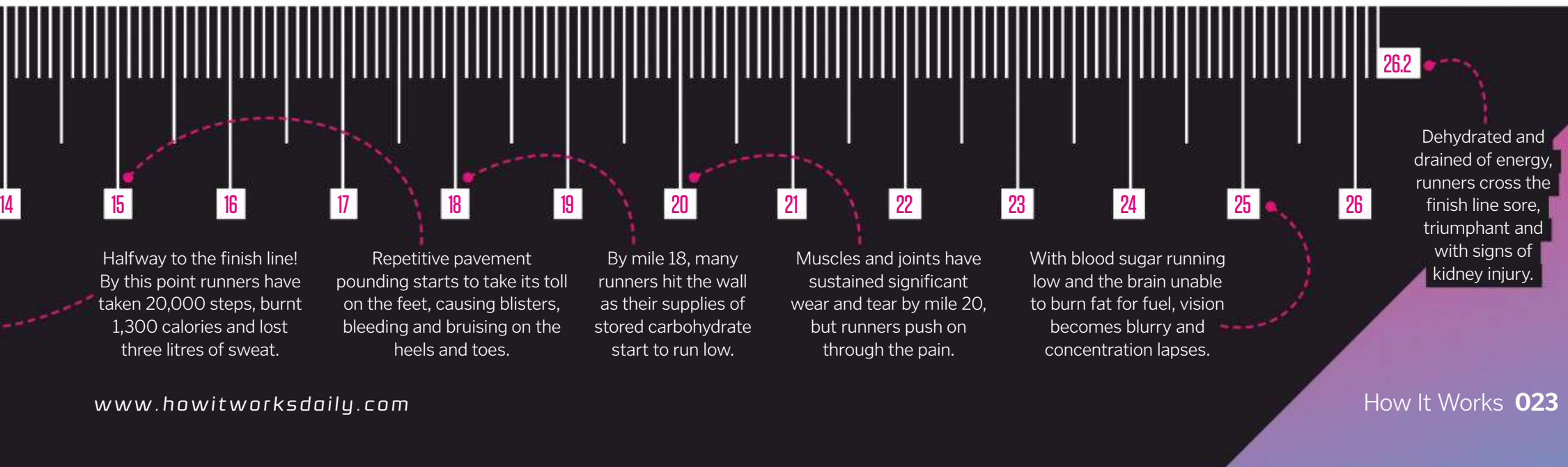
© Getty

Depleted sugar stores cause a painful energy dip mid-marathon

HITTING THE WALL

Two in five runners can expect to 'hit the wall' during a marathon. Hitting the wall describes the painful energy dip that happens when the body's sugar stores run dry. We all have a fast-access fuel reserve called glycogen. It's a carbohydrate made from thousands of chemically bonded glucose molecules. It's present in every muscle, and there's a large store in the liver equivalent to around 650 calories of instant energy. During prolonged exercise, the liver floods the blood with sugar to help keep the muscles topped up, and the more intense the exercise, the faster this sugar rush occurs. But when all the sugar is gone, energy levels crash.

Exactly when a runner will hit the wall depends on how much glycogen they have stored, how hard they're running and how well they trained. Over time muscles can adapt to burning fat as fuel instead of glycogen. This keeps the sugar stores going for longer, keeping the wall at bay.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26.2
Halfway to the finish line! By this point runners have taken 20,000 steps, burnt 1,300 calories and lost three litres of sweat.
Repetitive pavement pounding starts to take its toll on the feet, causing blisters, bleeding and bruising on the heels and toes.
By mile 18, many runners hit the wall as their supplies of stored carbohydrate start to run low.
Muscles and joints have sustained significant wear and tear by mile 20, but runners push on through the pain.
With blood sugar running low and the brain unable to burn fat for fuel, vision becomes blurry and concentration lapses.
Dehydrated and drained of energy, runners cross the finish line sore, triumphant and with signs of kidney injury.

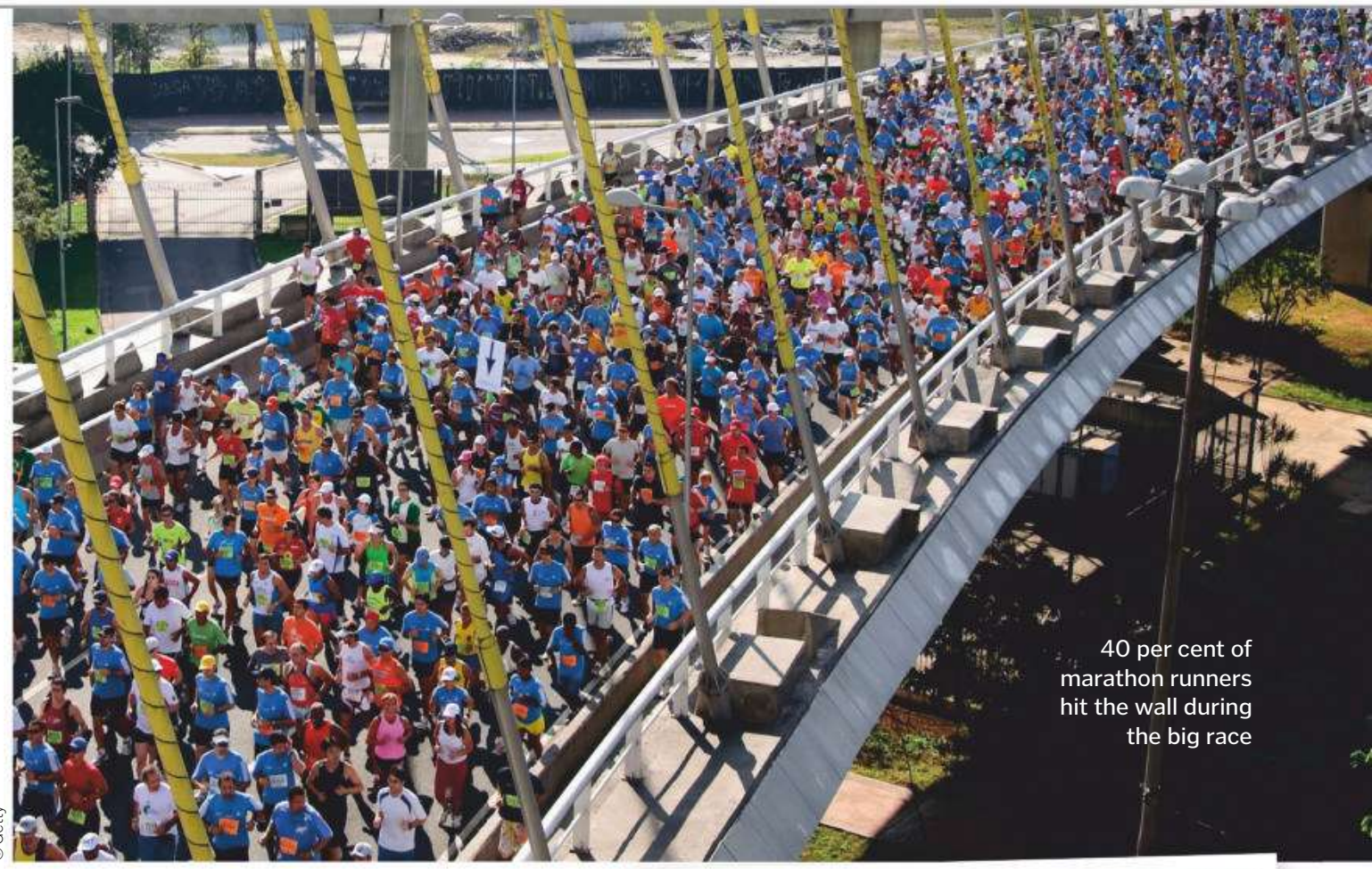
most elite athletes, fat is the main energy source, even when they're running at 85 per cent of their maximum capacity. But in untrained runners, even when there's plenty of oxygen, the body can't break fat down fast enough to keep the muscles working. Endurance training helps muscles to improve their ability to use fats for fuel. Over time muscle cells start to make more of the enzymes that they need to break down fat, and they stop depending so heavily on sugar.

A final change that the body makes during marathon training is to alter how it uses all that extra energy – its 'running economy'. The more efficient a runner's movements, the less oxygen and fuel they need to burn to travel at the same speed. Improvements here range from subtle tweaks to stride length through to major changes in muscle organisation.

Unlike weightlifting, endurance training doesn't increase muscle size. In fact, it tends to make muscles and muscle fibres thinner. But this is beneficial. A size decrease helps nutrients and waste products to move more easily, both inside the muscle cells and to and from the surrounding fluid. At the same time the number of small blood vessels around each muscle fibre increases. This keeps fresh nutrients coming in and waste products moving out, helping the muscles to work for longer without tiring.

The effects of marathon training last long after race day ends. Body mass drops as the muscles consume excess fat reserves, blood fats called triglycerides fall and 'good' HDL cholesterol goes up. Resting heart rate also falls – a measure of heart health.

These powerful effects on the body aren't without their risks. It's estimated that novice runners will endure 30 injuries for every 1,000 hours they spend on the road. Each year around one in three novice runners will get hurt. But according to doctors, the long-term benefits of endurance training far outweigh these risks.



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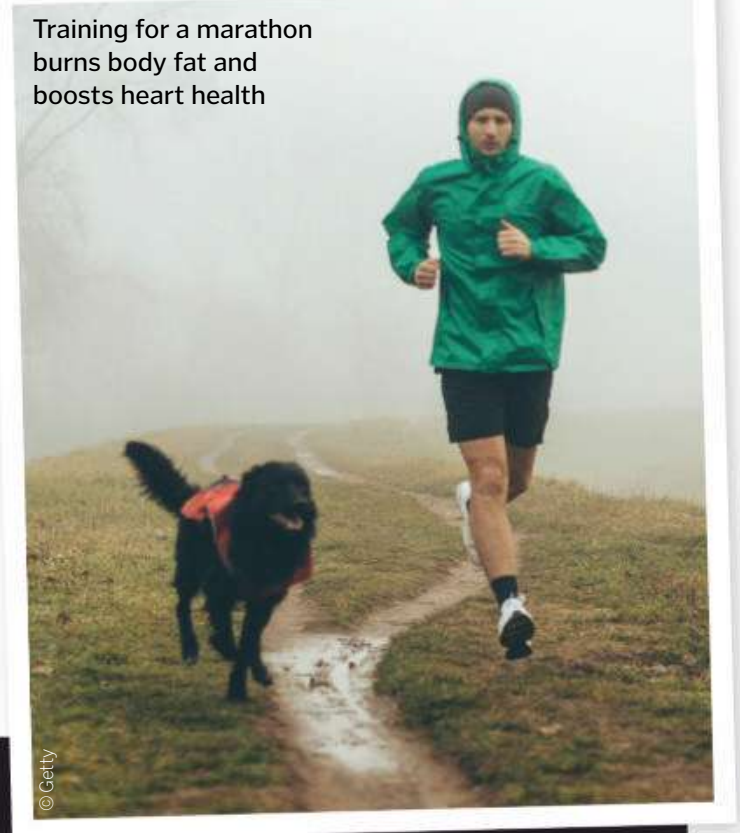
40 per cent of marathon runners hit the wall during the big race



Training for a marathon burns body fat and boosts heart health

© Getty

"MARATHON TRAINING UNLOCKS ACCESS TO THE BODY'S FAT STORES"

© Getty

MARATHON RECOVERY

Six science-backed ways to repair after the big race

Balanced meal

Marathon runners burn 100 calories per mile, so replenishing supplies is a priority post-race. Carbohydrates and fats restore lost energy, while protein supports muscle repair.

Electrolyte drink

Runners lose a litre of sweat an hour, and it's not just water – sweat contains sodium and potassium salts. To rehydrate properly, all three need replenishing.

Ice-cold bath

Muscles sustain micro-tears during long-distance running, triggering an inflammatory response. Ice-cold water helps to reduce the swelling, relieving pain and hastening healing.

Wound care

Hours on the road can rub the skin raw. Covering wounds with plasters and avoiding tight clothing helps to prevent infection and minimise discomfort.

Sports massage

Post-run muscle tightness can delay healing. A massage stretches damaged tissue, relieving tension and boosting blood flow so that the fibres can start to heal.

More running

Muscles produce waste for days after a big run. Gentle exercise in the days that follow can help to shift excess lactic acid.

All images © Getty

1/150,000

1 in 150,000 runners die during a marathon attempt

Energy gels have the same amount of carbohydrate as bananas

2,600 CALORIES

Marathon runners burn 2,600 calories during the race

2%

Runners lose a small amount of their body weight by sweating

160 BEATS PER MINUTE

The average heart rate during a marathon is 160 beats per minute

MARATHONS BY NUMBERS

840ml

The stomach can only process 840ml an hour during a race

4

Legs endure impact forces of four times a runner's weight

2:01:39

The world's fastest marathon time is 2:01:39

19 TO 26.2

Miles 19 to 26.2 are the most dangerous

Caffeine boosts run performance by releasing fatty acids into the blood

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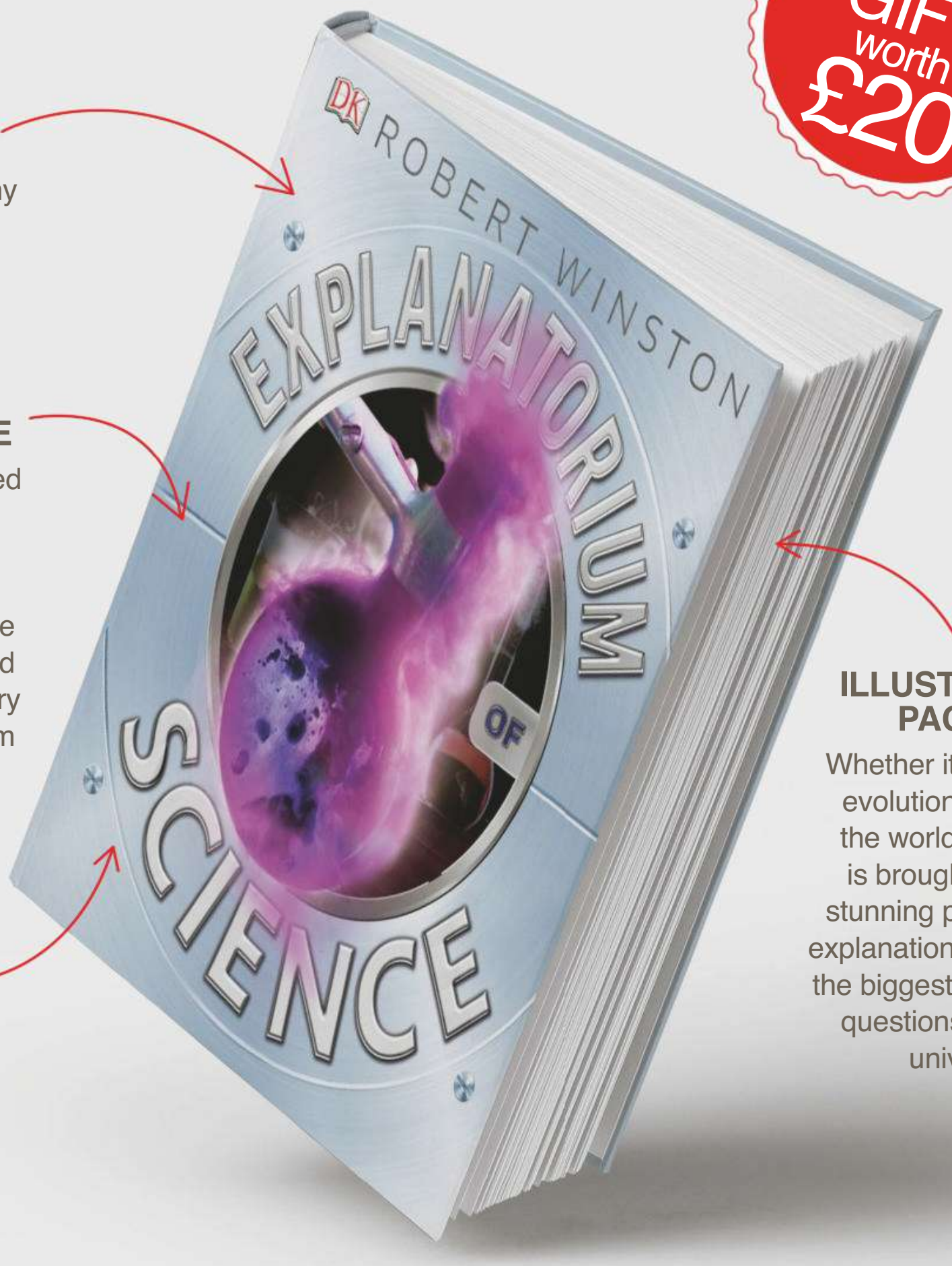

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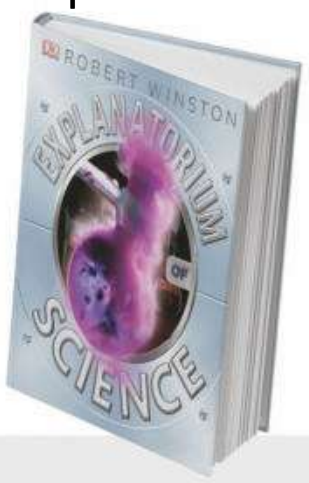

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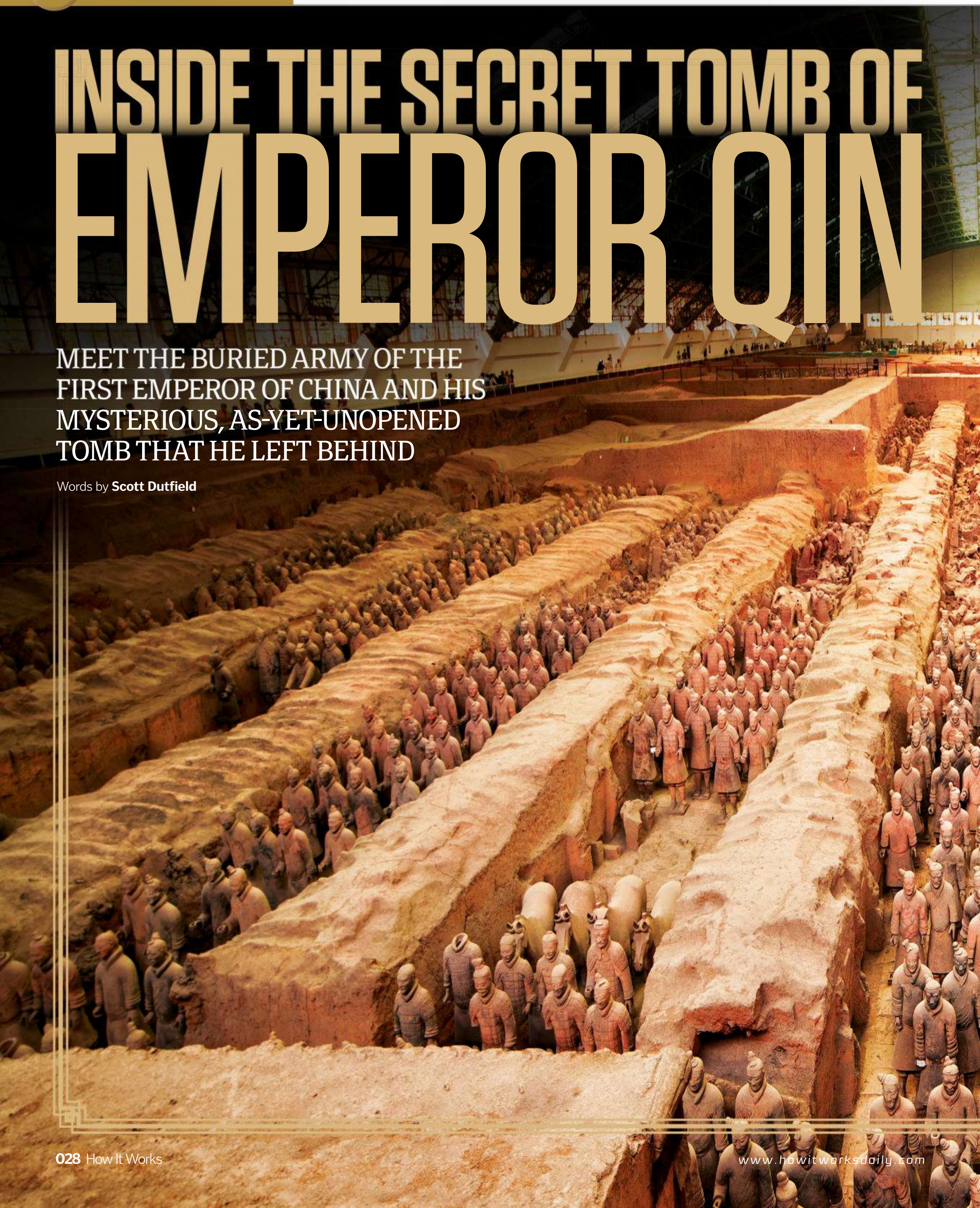
INSIDE THE SECRET TOMB OF EMPEROR QIN

MEET THE BURIED ARMY OF THE FIRST EMPEROR OF CHINA AND HIS MYSTERIOUS, AS-YET-UNOPENED TOMB THAT HE LEFT BEHIND

Words by **Scott Dutfield**



DID YOU KNOW? *Emperor Qin was also responsible for the creation of the Great Wall of China*

© Getty

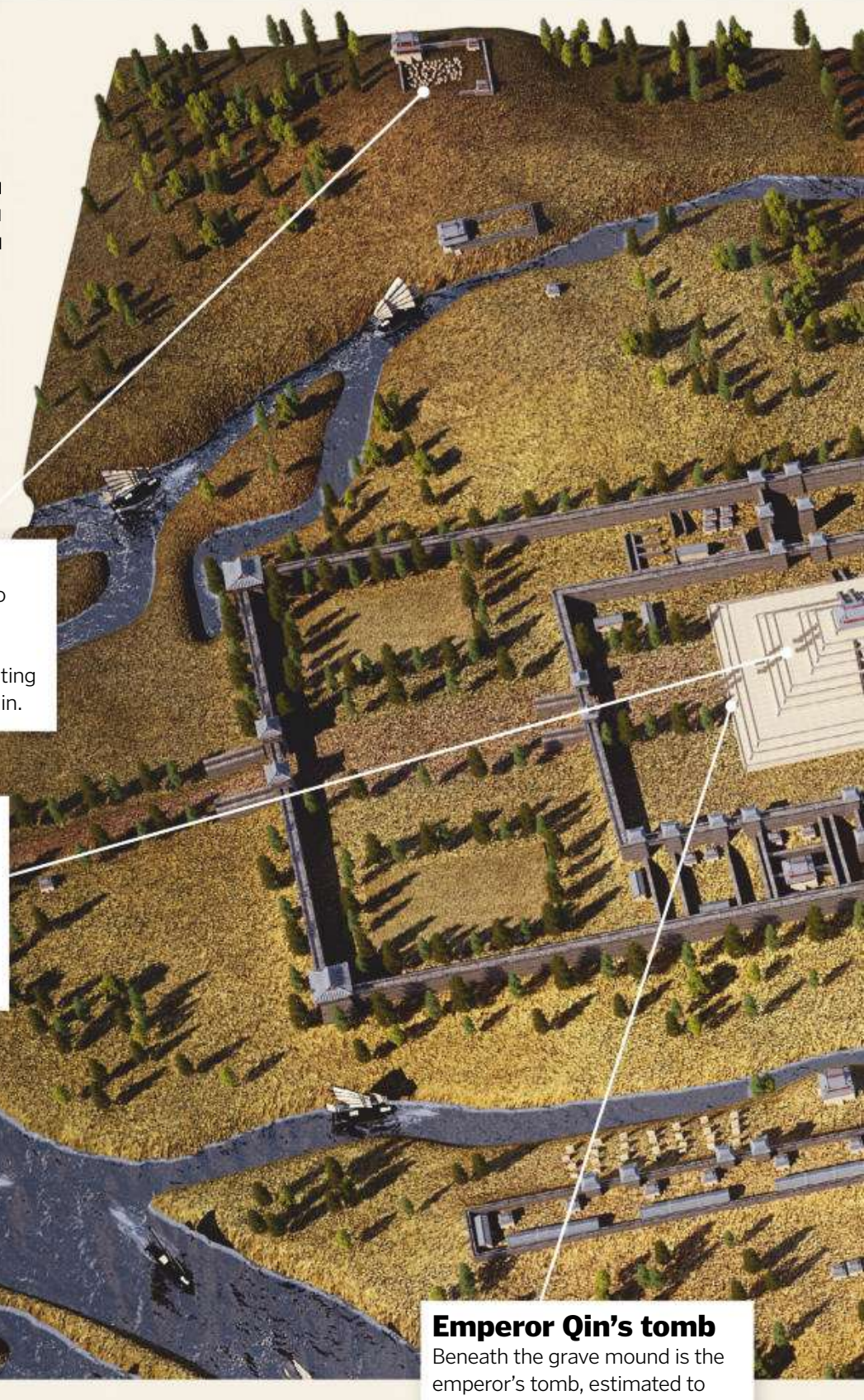
UNEARTHING THE CITY BENEATH THE SURFACE

Emperor Qin's mausoleum appears more like a buried civilisation than a place of rest

Imagine the looks of surprise on the faces of a group of well diggers when, while breaking ground in the hope of finding water, they instead uncovered a network of underground chambers housing thousands of ancient stone soldiers, still standing to attention.

Discovered outside of Xi'an, the capital of the Shaanxi Province in central China, the mausoleum of Qin Shi Huang, the First Emperor of China, has provided one of the largest bounties of ancient artefacts ever discovered. Over 8,000 terracotta warriors have been uncovered at the ancient site since its initial discovery back in 1974 in arguably one of the greatest finds in archaeological history.

Around the fifth to third century BCE, China was divided into seven states, each waging war on another during a time known as the Warring States Period. As the leader of a western state called Qin, Ying Zheng rose to even greater power after emerging triumphant in the battles against the other six states in 221 BCE. After his victory, Ying Zheng united the feuding regions and declared himself the First Emperor of China under the new name of Qin Shi Huang. As emperor of this collective, it's well documented that Qin Shi Huang was a dictator. Some accounts detail an incident in which 460 scholars were executed for disagreeing with Qin's government, and their texts were burned or confiscated. Having assembled a living army comprising of hundreds of thousands of soldiers, Emperor Qin turned his attention to a palace and military force he desired not only in the living world, but one he could reside with in death.



Workers' graves
The craftsmen and labourers who spent 38 years building the mausoleum complex are buried together with ceramic tiles indicating their name, rank and place of origin.

Grave mount
This pyramidal tomb of earth was originally piled to a height of around 115 metres. However, over time the mound has eroded to its current height of around 55 metres.

Emperor Qin's tomb
Beneath the grave mound is the emperor's tomb, estimated to cover an area of around 180,000 square metres. The tomb lies 30 metres below the surface.

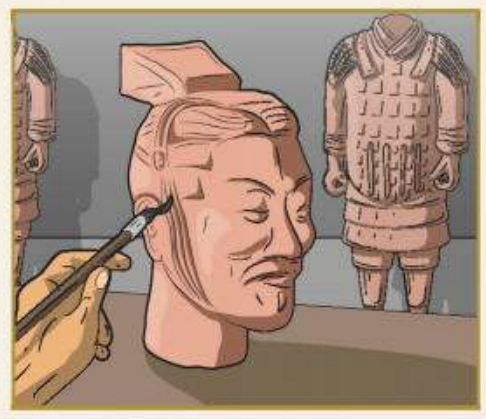
How to build a terracotta warrior

Each of these ancient stone soldiers was made from terracotta, or 'baked earth'. Here's how they were assembled

1 The base
Moving up from the square base, the feet and legs were sculpted with muscle and bone details. The upper portion of the body was created by wrapping strips of clay to form the body, beating the final torso into the desired shape and size.

2 Moulding the arms and the head
Created separately, the head and the arms were formed by packing clay into moulds to create a rough shape. Once formed, facial features and hairstyles were hand carved by master craftsmen.

3 Drying out
All the components of the clay warrior were left in the shade for around 24 hours to dry out and harden.



4 Adding details
Once hardened, armour and military dress details were carved into the torso and head. Once completed the hands were attached by gluing them to malleable clay.

Mutilated skeletons
There have been around 90 graves unearthed since the mausoleum's discovery. Many were found to be empty, but some had mutilated human remains at their doors.

Walls
There are two walls surrounding the mausoleum; the inner wall has a perimeter of around 3,840 metres, and the outer wall reaches 6,210 metres.

Terracotta army
Found in three distinct pits, more than 8,000 terracotta warriors stand in droves 1.5 kilometres away from the outer walls of the mausoleum.

© Illustration by Nicholas Forder

The mercury-rich mineral cinnabar is likely the source of Emperor Qin's mercury consumption

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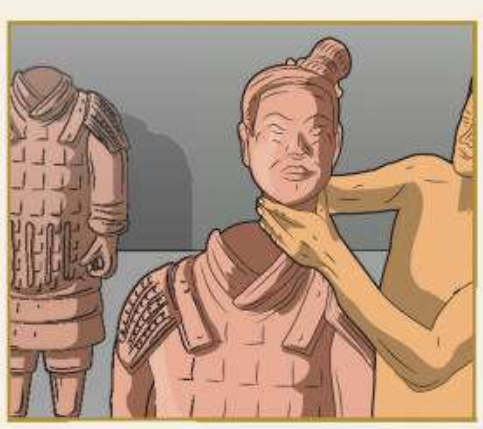
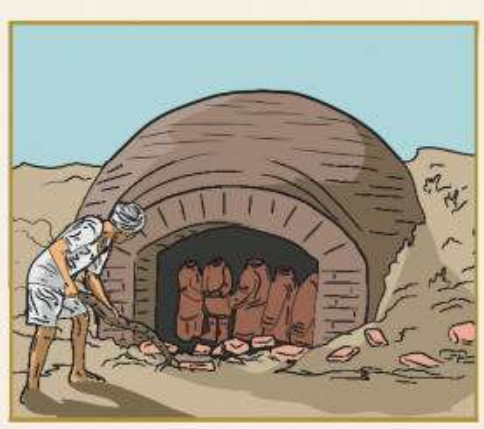
Ying Zheng, later Emperor Qin Shi Huang, rose to power and controlled the Qin state in 246 BCE

The pursuit of immortality

Ascending to the throne of the Qin state in 246 BCE at only 13 years old, Emperor Qin Shi Huang almost immediately began plans for his elaborate royal mausoleum. Emperor Qin had a fascination with the afterlife and made repeated attempts to evade the mortal eventuality of death. However, it's widely believed that it was this pursuit of immortality that led to his death in 210 BCE. Mercury is thought to have been the key ingredient in the emperor's 'elixir of eternal life'. Although it's still not fully understood how the mercury was consumed, it's safe to say the First Emperor was not simply drinking the liquid metal from a cup, due to its highly neurotoxic effects that would have killed him in a short space of time. What might have been a more likely method of consumption was either taking pills of the mercury-sulphide mineral cinnabar or by crushing the rock into wine. Nevertheless, the scarlet mineral did not unlock the gates of immortality and instead sent him deep underground to his impressive mausoleum before he could reach his 50th birthday.



5 Mounting the head
The final section of the warrior to install was the head, which slotted into the torso cavity. This had been created by building the torso around a sackcloth which could be later removed, leaving a hollow cavity behind.



6 Bake it
Having placed ventilation holes around the raw model before baking, each soldier was heated using a kiln, much like in modern-day pottery, to temperatures of around 1,000 degrees Celsius.

© Illustrations by Ed Crooks

7 Add lick of paint
Next lacquer extracts from trees were painted over the freshly baked statues. Different pigments from coloured minerals and even bone were then mixed with eggs to form a paint to cover the entire soldier.

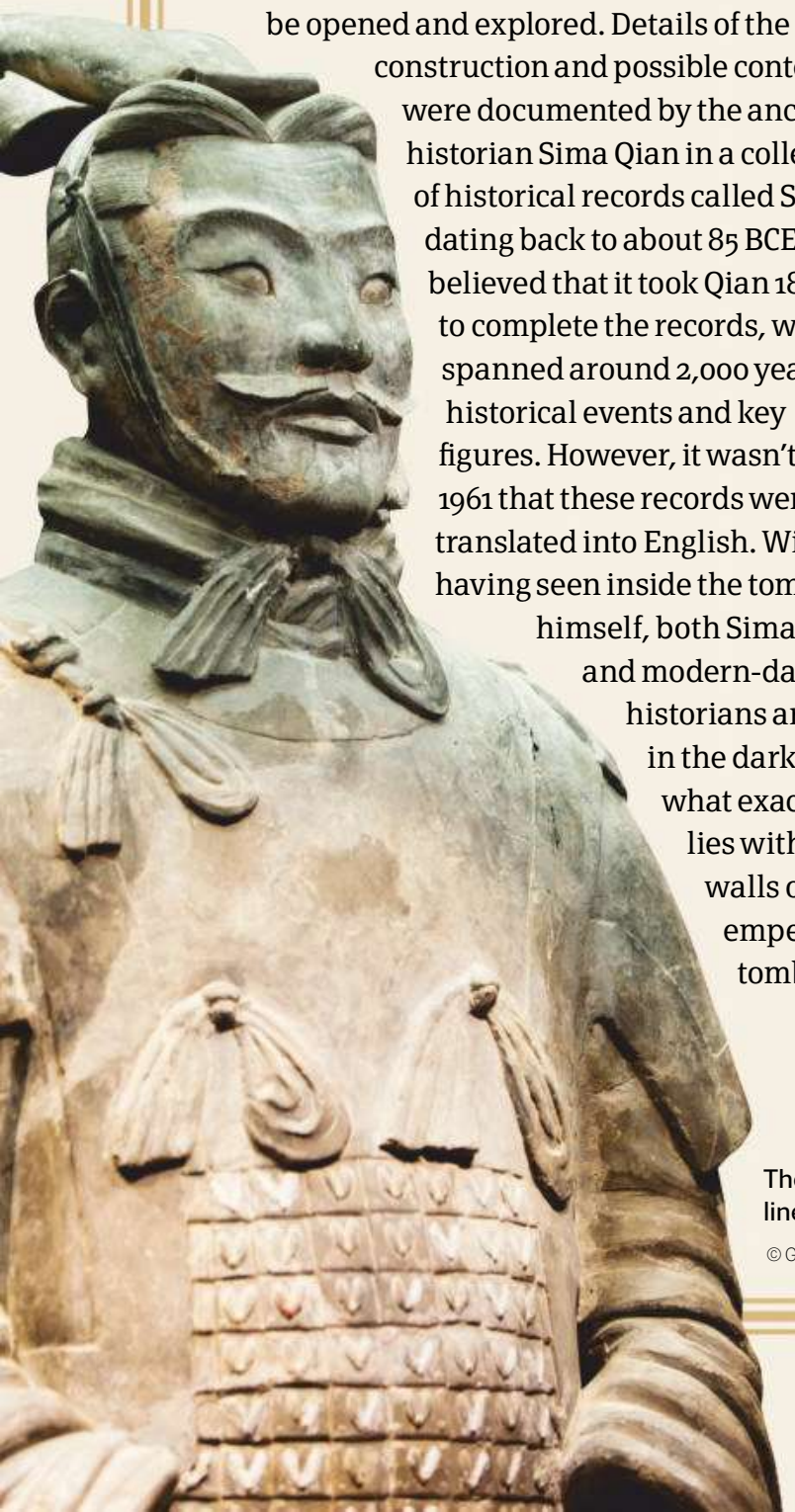
AR ZONE!

Source: Wiki/Aaron Zhu

Qin is thought to rest around 30 metres below the grassy grave mound, which is now a popular tourist attraction

Taking around 38 years to construct at the hands of an estimated workforce of 720,000 men, the mausoleum of Emperor Qin is an underground palace filled with pits and buried chambers to house everything the emperor believed he needed and wanted to take with him into the afterlife. This included the creation of the terracotta army, along with other sculptures such as military officials, civil servants, acrobats and horses. However, clay-made sculptures aren't the only residents of the mausoleum. As a ruthless leader, Emperor Qin also wanted the actual bodies of some of his servants, officials and concubines – the emperor's mistresses – to join him in the hereafter. In pits found around the tomb are the remains of those chosen to follow him into the afterlife. Some of these unfortunates are thought to have been buried alive.

What remains a mystery about the mausoleum is what exactly lies within Emperor Qin's tomb. The final resting place of the First Emperor is thought to be hidden deep within the heart of a grassy mound near the Terracotta Warriors, along with precious gems, personal possessions and even some booby traps. Since the discovery of its location, the tomb has yet to be opened and explored. Details of the tomb's construction and possible contents were documented by the ancient historian Sima Qian in a collection of historical records called Shiji, dating back to about 85 BCE. It's believed that it took Qian 18 years to complete the records, which spanned around 2,000 years of historical events and key figures. However, it wasn't until 1961 that these records were translated into English. Without having seen inside the tomb for himself, both Sima Qian and modern-day historians are still in the dark about what exactly lies within the walls of the emperor's tomb.

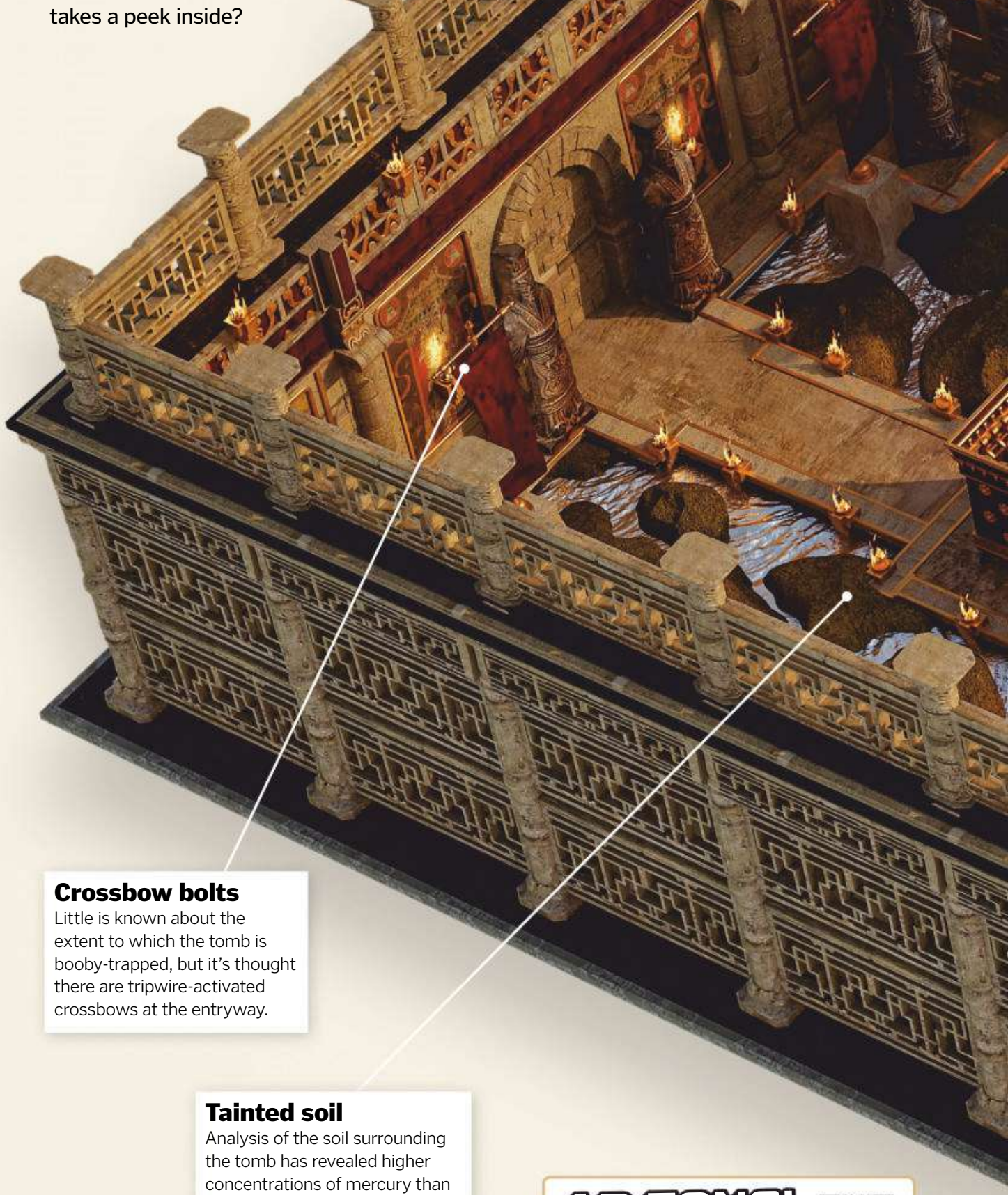


The terracotta warriors are lined up in their hundreds

© Getty

INSIDE THE UNOPENED TOMB

What secrets lie in wait for when the first archaeologist takes a peek inside?



Crossbow bolts
Little is known about the extent to which the tomb is booby-trapped, but it's thought there are tripwire-activated crossbows at the entryway.

Tainted soil
Analysis of the soil surrounding the tomb has revealed higher concentrations of mercury than seen in the rest of the region, leading archaeologists to believe the mercury lakes may have leached away into the soil.

AR ZONE! SCAN HERE

Do not enter

It seems strange that one of the world's biggest archaeological discoveries has not been completely excavated. The First Emperor has lain undisturbed in his mausoleum for decades since its discovery, which has led many to wonder why. Unfortunately the answer is still unclear, with some suggesting it's a sign of respect for the emperor. Others believe the Chinese authorities haven't opened it out of fear of how the contents would react to being exposed to the outside world. One reason for leaving it sealed may be because of the lakes and rivers of mercury that are presumed to flow within: deadly mercury vapour may have collected in the musty tomb air over thousands of years.

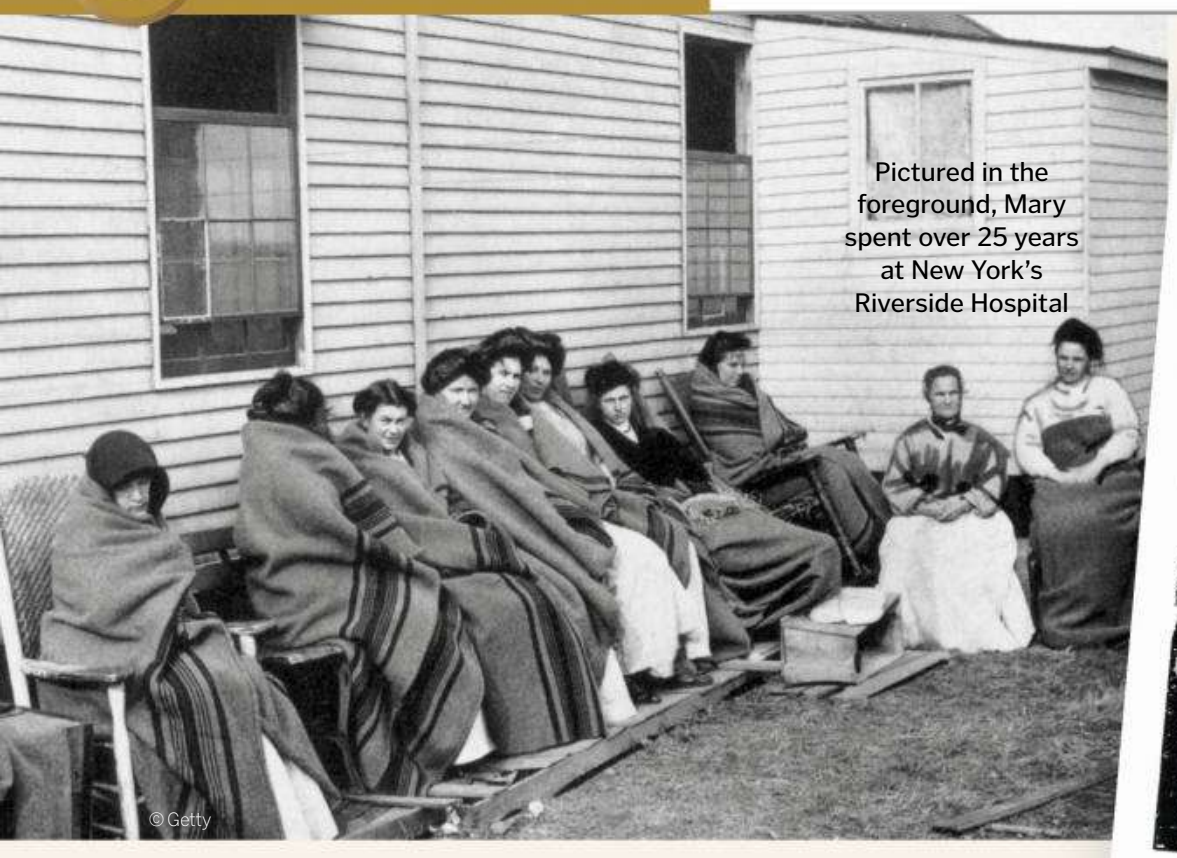
Tomb
Sitting in the centre of the tomb is thought to be the coffin of Emperor Qin. Some believe that it is constructed from copper.

Night sky
It's believed that the ceiling of the inner tomb is a painted night sky, bejewelled with precious gems as stars.

Bronze mountains
Ancient records suggest that the emperor's tomb sits amid undulating mountains of bronze, a material seen readily in unearthed artefacts and sculptures.

Mercury rivers
Continuing his belief in the immortal power of mercury even in death, rivers and lakes of mercury are thought to surround the final resting place of the emperor.

© Illustration by Nicholas Forder



Pictured in the foreground, Mary spent over 25 years at New York's Riverside Hospital

© Getty

© Getty

This artist's depiction of Mary from the early 1900s shows her adding the deadly ingredient

Who was Typhoid Mary?

How a cook's recipe of ignorance and ice cream resulted in the infamous outbreak of a deadly disease

Mary Mallon was an exquisite cook. The meals she prepared were so well received that the Irish immigrant was offered numerous jobs cooking for wealthy families across New York. Unfortunately, while her abilities in the kitchen could have made her a culinary name, in the end it was her inability to wash her hands that gained her a new nickname: Typhoid Mary.

Typhoid is a bacterial infection caused by *Salmonella typhi*, which leaves the infected suffering from a fever and problems throughout their digestive system. Usually typhoid is spread through food and water contamination and poor hygiene levels, but Mary caused outbreaks in the relatively sanitary homes of wealthy families.

Everywhere Mary cooked, typhoid descended upon the households, and it wasn't long before the link between her and the outbreaks was discovered. Mary's reluctance to wash her hands properly led to plates of infection being served to everyone she cooked for.

Despite dozens of people falling ill around her – and with three dropping dead – remarkably Mary still showed no sign of infection. Because of this, when Mary was told by authorities that she was carrying the disease, she denied it. Up to six per cent of people infected with *Salmonella typhi* are thought to be asymptomatic carriers, and Mary was one of them. As the bacteria continued to live inside her, she showed no signs of illness and became a mass spreader.

Unwilling to give up her job, Mary changed her name and continued cooking in denial of her harmful ways. Responsible for suffering, death and even a hospital outbreak, at the time she and many others were unaware of the link between handwashing and some diseases. The story of Typhoid Mary shows how this simple act can defend against an outbreak of disease.

5 FACTS ABOUT TERRIBLE TYPHOID

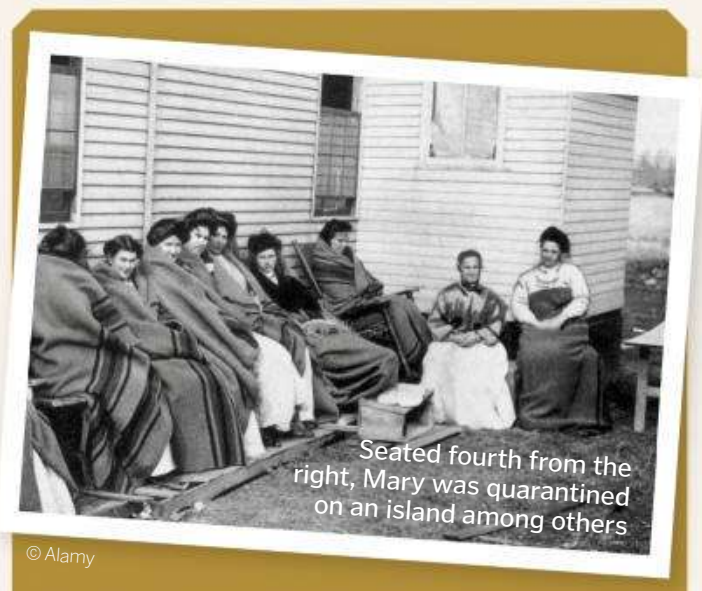
1 Death rates
When left untreated, typhoid is fatal in 10 to 30 per cent of people.

2 Symptoms
The symptoms of typhoid include fever, diarrhoea, nausea and vomiting.

3 Treatment
The only way to treat typhoid is using antibiotics, while typhoid conjugate vaccines act as a form of prevention.

4 Entering the bloodstream
The Salmonella bacteria responsible stays in the intestine for one to three weeks before entering the bloodstream.

5 Current day
Today between 128,000 and 161,000 people die from typhoid every year.



Seated fourth from the right, Mary was quarantined on an island among others

© Alamy

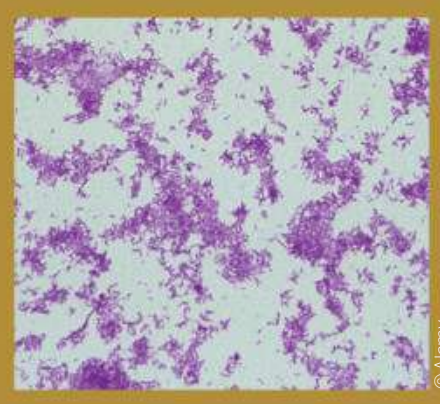
Who blamed Mary?

Charles Henry Warren was a rich man, working as a banker and living in a large family home to be proud of. When six members of his household came down with a disease rife in poorer communities, Warren was shocked. He needed an explanation as to why typhoid fever, which he thought only existed in the slums, was spreading through his immaculate home.

A sanitary engineer was hired, who looked into all the workers at the house. When he came across Mary, a cook who had begun working there weeks before, he found that the Warren household wasn't alone in its sudden illness. Seven other families who Mary had served had also reported having the same symptoms.

Infected ice cream

Hygiene is essential in any kitchen, as people not only come into contact with its products, but ingest them. This being said, even when germs are spread to food, many end up being cooked at temperatures high enough to kill them. One of the main questions of the investigation into the typhoid outbreak was how so many fell ill: the answer came when exploring the types of dishes Mary served. One of her most popular treats was a peach ice cream dessert. Any microbes reaching this food would not be heat treated. Mary's unwashed hands were used to hold the peaches while she cut them, a crucial factor in this disastrous typhoid outbreak.



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Salmonella typhi causes typhoid infections once ingested

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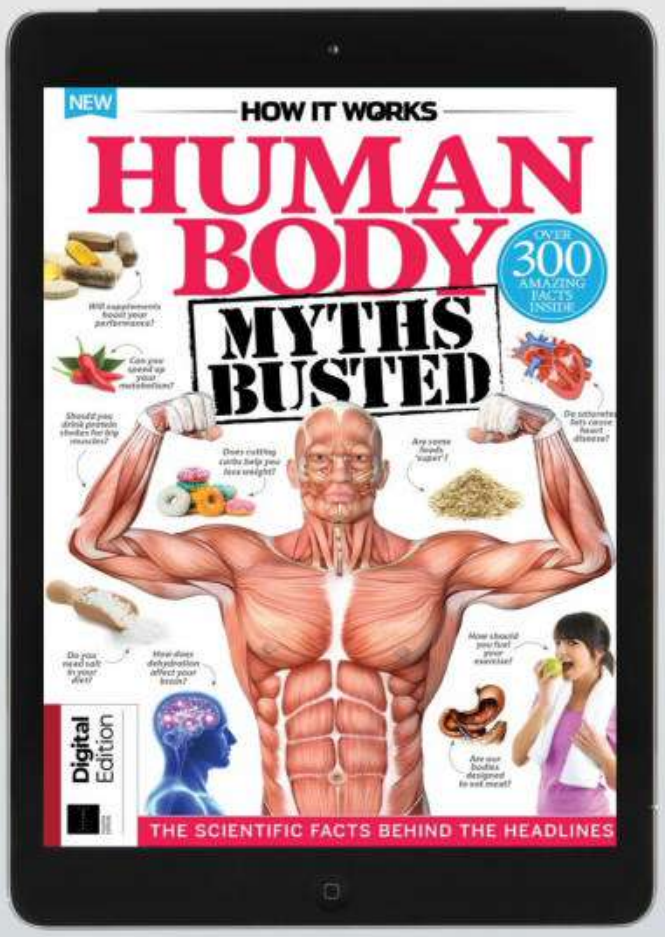
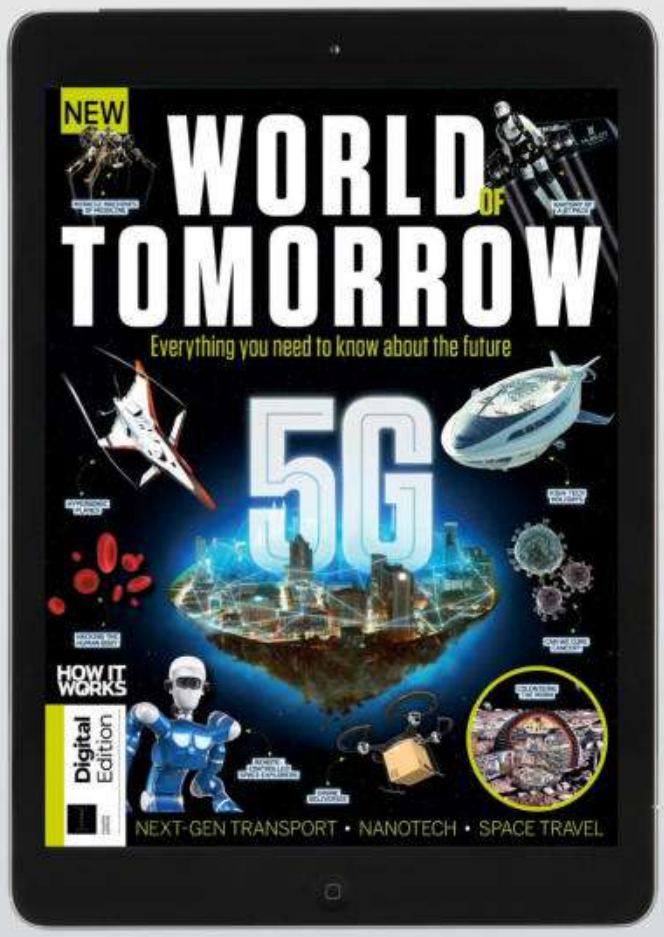


Human body myths busted

It's important to dispel dietary myths about food, in particular for the younger generation, who face the prospect of an increased risk of ill health with rising rates of obesity. With the **How It Works Book of Human Body Myths Busted**, you can learn the truth behind the biggest health and body myths of our time and discover what is really going on inside your body when you eat, drink and exercise.



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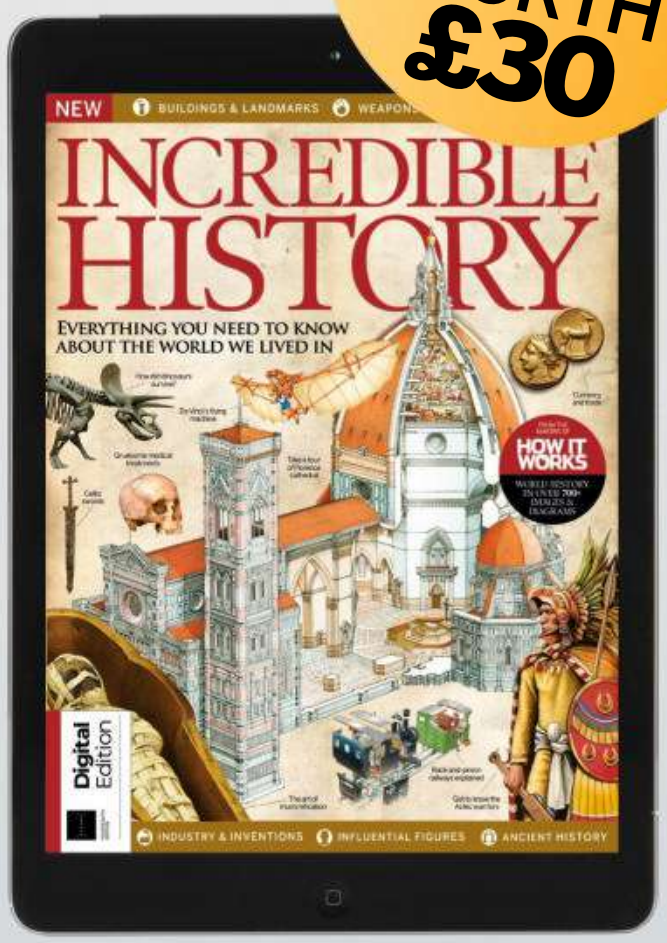

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What is love?

From biochemical addiction to evolutionary perks, discover the science behind our most powerful emotion

Words by **Ailsa Harvey**

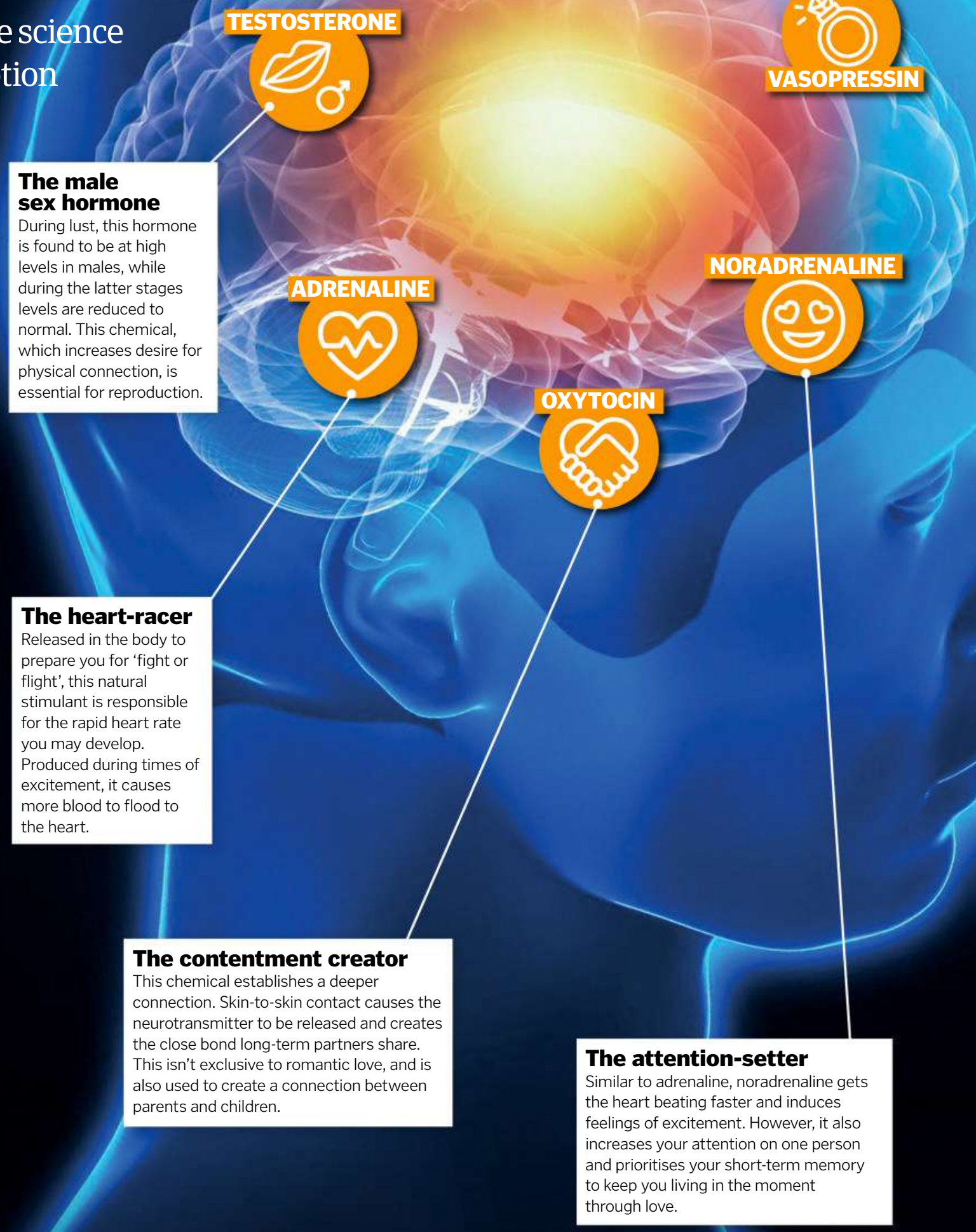
The word 'love' is often thrown around and associated with almost anything we feel drawn to. Whether it is a person, object or an abstract idea, you can love them all. But what does it really mean to love? Films often feature romantic love as part of the main plot. Its unpredictability, intensity and power make for an exciting storyline – just as it does in reality. While fiction often plays with an overly simplified, romanticised view of it, love is more than a fairy-tale dream. Love experienced in real life is a complex affair.

Where in the body do you feel love? It can feel like it is taking over your entire being, and most of your body does actually experience physical changes. Your heart is just one of the impacted organs, but is also the one that we romanticise the most. As we come to terms with the uncontrollable feelings of initial attraction to another person, our hearts can get overstimulated. At the core of our being, it is one of the most obvious effects we notice. The heart has become the symbol of love, dating back as far as the Middle Ages.

The first feeling we may associate with being in love is usually euphoria, but from the moment you discover an attraction to someone to the latter stages of love, a range of sensations take over. From compassion and desire to obsession and anxiety, both positive and negative emotions can come into play.

What makes this feeling even more overwhelming is its uncontrollable factor. Love is felt subconsciously, to the extent that some people who are in love don't even realise they are. But love doesn't exist purely to add a touch of excitement to your life. Your body responds to further meaning relationships in order to keep the human race alive.

Although less important in our modern world of 7.8 billion people, when survival was more of a priority before the dawn of civilisation, the human body evolved to keep reproduction levels high. The ability to form this intense connection and attachment to another human being led to procreation and a parental team who were able to work


TESTOSTERONE
The male sex hormone
During lust, this hormone is found to be at high levels in males, while during the latter stages levels are reduced to normal. This chemical, which increases desire for physical connection, is essential for reproduction.
VASOPRESSIN
ADRENALINE
The heart-racer
Released in the body to prepare you for 'fight or flight', this natural stimulant is responsible for the rapid heart rate you may develop. Produced during times of excitement, it causes more blood to flood to the heart.
NORADRENALINE
OXYTOCIN
The contentment creator
This chemical establishes a deeper connection. Skin-to-skin contact causes the neurotransmitter to be released and creates the close bond long-term partners share. This isn't exclusive to romantic love, and is also used to create a connection between parents and children.
The attention-setter
Similar to adrenaline, noradrenaline gets the heart beating faster and induces feelings of excitement. However, it also increases your attention on one person and prioritises your short-term memory to keep you living in the moment through love.

"Your heart is just one of the impacted organs, but is also the one that we romanticise the most"

The monogamy maker
Similar to oxytocin, vasopressin establishes part of the attachment phase. This particular chemical has been linked to loyalty between couples.

The female sex hormone
Produced by the ovaries as well as the adrenal glands and fat cells, oestrogen increases a woman's desire for physical contact during the lust stage. Abnormally low levels of this hormone can negatively impact general mood.

The rewarder
This neurotransmitter is used by your nervous system to send messages through the body. When in love, this chemical activates the reward circuit and creates a sense of pleasure from being in love.

OESTROGEN

DOPAMINE

PHENYLETHYLAMINE

SEROTONIN

ENDORPHINS

The under-performer
During the attraction phase, production of this chemical has been shown to reduce. Creating a chemical balance similar to someone with Obsessive Compulsive Disorder (OCD), this could be the reason some people show obsessive qualities during love.

The painkillers
Released to create a soothing feeling, these are the body's natural painkillers. During physical contact with a loved one, endorphins increase and create a positive mood. Long-term relationships are thought to rely on this chemical.

The love drug
Released by the brain, this molecule stimulates the entire central nervous system. Naturally creating addictive properties similar to those found in the drug MDMA and coffee, this chemical creates the initial, intense feelings during lust.

Sniffing out the perfect partner

You might discover a lover based on initial visual attraction, their beaming personality that comes through during the first conversation you share or maybe even through a recommendation from a mutual friend. However, what you may not have known is that you are subconsciously analysing their genetic make-up.

This might not be the first thing you grow to love about someone, but your sense of smell creates an attraction to people with a different immune system to your own. As an incredibly beneficial evolutionary tool, our bodies aim to partner up with someone with the potential to create offspring with the best chance of survival.

This is possible because a person's unique smell is created by the same sets of genes that make up their immune system, enabling us to detect differences in genes through scent. The saying 'opposites attract' couldn't be more applicable in this situation. While you may not notice the subtle scents of everyone around you, your brain does. More often than not, you will find yourself attracted to those who don't smell like you.

© Getty

We all inherit a different set of genes which respond to infections

© Alamy

happily together to protect their offspring and ensure that they thrive.

While the science behind love is intriguing to study, translating these reactions in the body into feelings is likely different for each person based on their body and unique experiences. Love has connotations of eternal happiness, but not everyone is built to manage these feelings. For two people to establish a trusting and growing relationship, being open to accepting love is essential. In the early stages, the body becomes vulnerable as physical and chemical changes induce a 'fight-or-flight' response. This is due to emotional strain being outside of comfortable levels. In some people who have experienced trauma, this fight-or-flight function becomes overdeveloped, as their bodies are used to danger. Each individual's brain needs to get used to rewarding the body with the chemicals of love. From there, connections with other humans can grow and be explored.

The love a parent feels for their child is often one of the most powerful kinds

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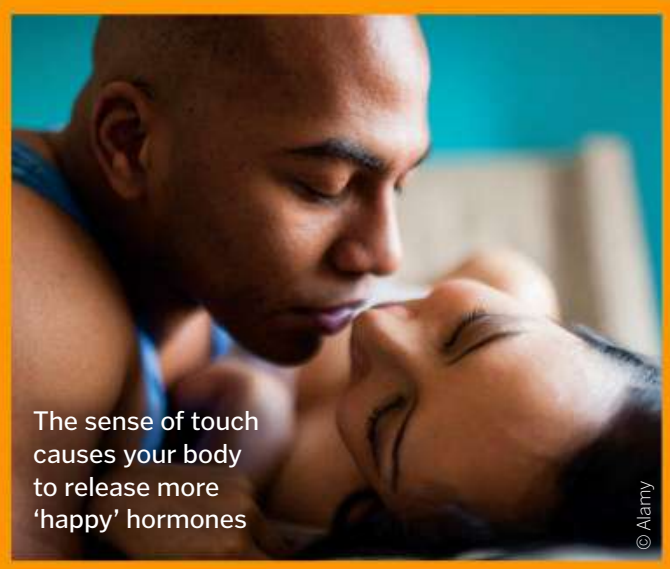
The three stages of falling in love



The sense of touch causes your body to release more 'happy' hormones

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LUST

During the lust phase, men and women release the hormones testosterone and oestrogen. Oestrogen is released by women and initiates a feeling of longing for physical closeness. Testosterone is produced by men, but females also produce it in smaller amounts. This hormone, like oestrogen, increases sex drive and establishes the first stage of falling in love. At the beginning the purpose is to have a physical relationship, rather than an emotional connection, which is yet to be built upon.

During the attraction phase people become less likely to think rationally

© Getty

ATTRACTION

The second stage continues some of the feelings felt through lust, but incorporates more of the emotional impacts. You will know if you have reached the second stage if you find your heart beating faster when around the person, you begin to feel nervous upon meeting them and you start to channel almost all of your attention on them. If you hear someone refer to being in the 'honeymoon phase' or saying that they have 'caught feelings', they are likely to be in this stage. This point in the process can instigate feelings of euphoria, but unfortunately it usually only lasts for a matter of months.

At the beginning of the attachment stage couples might move in together, get married and plan a life together

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ATTACHMENT

As the relationship becomes more established, hormones responsible for human bonding come into play. Oxytocin is the main hormone responsible for the differentiation in this final stage of falling in love. Working to create a strong emotional attachment, this hormone is released along with dopamine – the hormone responsible for happiness. As you have continuous contact with one partner, the levels of dopamine released alongside the oxytocin provide a sense of reward and keep couples returning back to the same person. This stage also establishes a sense of security and a need to protect the other.

Q&A Dr Michael Merzenich

As a pioneering neuroscientist, Dr Merzenich has been granted close to 100 patents. Using five decades of research into brain plasticity, he explains the brain's key role during love

Is love a real feeling, or a concept based on a series of strong feelings in the brain?
Love is the real convergence of powerful neurological effects that distort your emotional balance in a wonderful form. Our brains are designed to support that progression to love, of course. That critical progression to procreation and loyal partner support is key to the survival of our social species. Love is more than lust or procreation. It's also about stable bonding and enduring attachments.

Through the brain's reward process, is all happiness capable of developing into love?
'Love' is a sloppy word. I might 'love' football because I've seen my team have so many wonderful successes and celebrated them so cheerfully many times in my past. I have learned to associate football with rewarding. I may 'love' my garden or my pub or my job. This use of 'love' explains neurological attachment, but this is quite a different thing from the love of another person, where there are more physical and chemical factors in play.

That person has a rich array of ways to interact with me – by voice, touch and emotion – that reward and surprise me. It is this combination that can excite me. And every kindness I deliver to them that they respond to also excites me through the same neurological processes. When two individuals do this well, that mutual co-excitation is just about the most powerful way that your brain can be engaged.

Are some brains more susceptible to love than others?
Sure. The machinery in the brain is constantly developing. Its health and powers are a product of their historic use. We 'exercise' them as we live a hopefully stimulating and rewarding life – and some lives are a lot more positively stimulating than others. A person that has had a terribly non-rewarding life will take longer to find themselves smitten. In addition, a kind and generous person is exercising their brain in ways that help set them up for love.

> *"Love is more than lust or procreation. It's also about stable bonding and enduring attachments"*

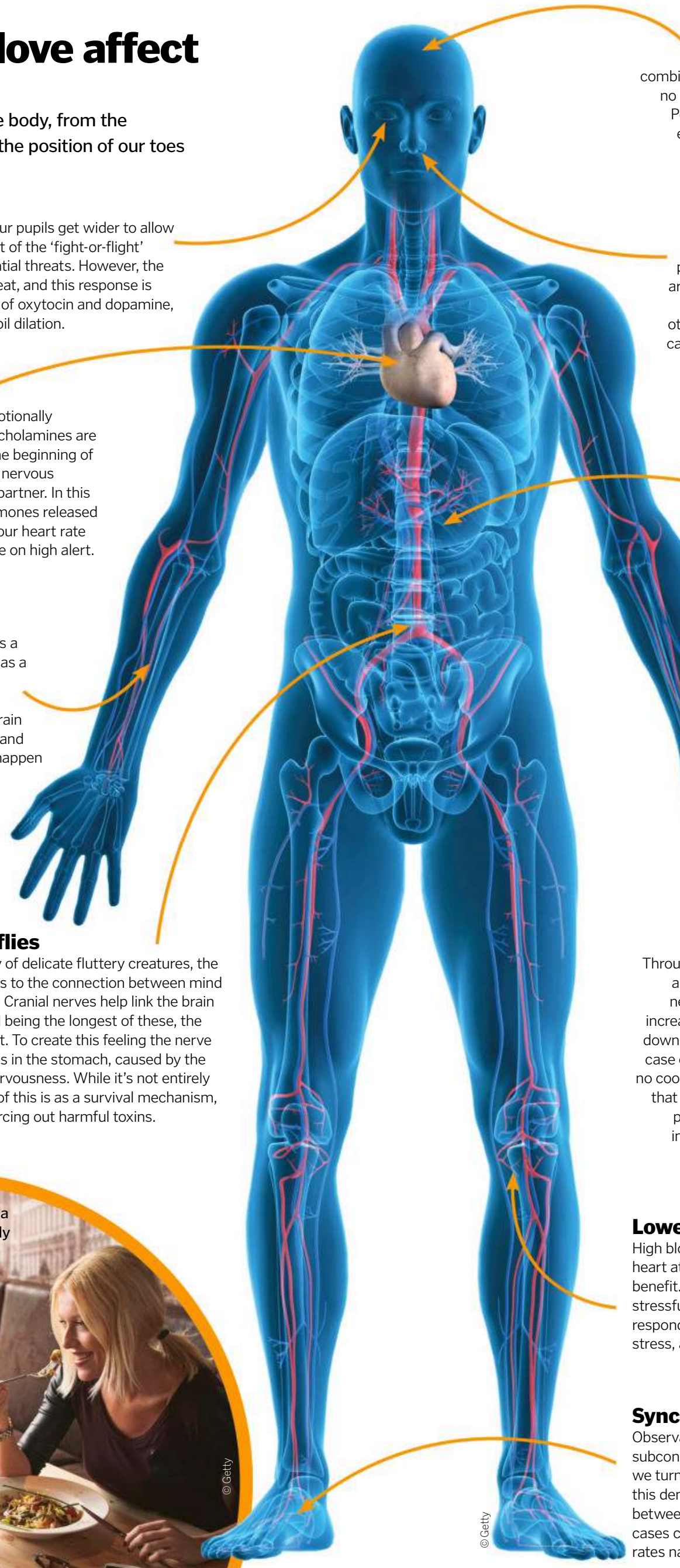
What do you find the most fascinating about the brain's role in love?
It's all rather miraculous. And yet, it's still all blood-and-guts biology. As a scientist, I've been very interested in how our evolution of these processes can come at a price. The rewarding and stimulating processes can go awry, creating a major source of human suffering. Sometimes this can cause issues with mental illness, addiction, criminality and violence. How can a person both love and beat their partner?
We are a long way down the path to answering questions like that one. We are working to evolve strategies for helping individuals drive their brain out of the kinds of ditches they can fall into – back to the thriving, loving human mainstream.

How much more is there to learn about love and the brain – do we have it all sussed?
Like many things in brain science, we have a pretty good understanding of it as a complex sequence of processes. We can see it happening in the brain through its major steps. At the same time, truly experiencing love is not the same as describing it through all of this organic biology, and it comes in diverse forms. I was very lucky to experience it as a young man – in my case with a mate for life – then with our progeny and their progeny and with my own parents. I have found love of different sorts, such as with a beloved friend and a dog or two.

Love isn't just felt for other people – humans get very attached to their pets

How does love affect the body?

Love takes over our entire body, from the chemicals in our head to the position of our toes



Mental health

Flooding the brain with an unfamiliar and complex combination of hormones and other chemicals, it comes as no surprise that love alters aspects of our mental health. Possessing a strong connection to someone else often enables people to manage stress and can help reduce symptoms of anxiety and depression.

Pheromone feels

Unlike the majority of hormones your body releases, pheromones are released outside the body. While you are secreting these chemicals, produced in your sweat, saliva and urine, you are also picking them up from other people. Detected in the nasal cavity, pheromones can act as chemical messengers, making you attracted to someone nearby. It is this phenomenon that may explain some people's belief in love at first sight.

Hormone production

Many of the hormones produced during love, while triggered by your brain, are produced by your adrenal glands. These are then released into the blood and pumped around your body in order to carry out their specific roles. During different stages of love, the brain is sending high volumes of signals to these glands, keeping them busy.

Pupil dilation

When you like what you see, your pupils get wider to allow more light in. This feature is part of the 'fight-or-flight' response to help evaluate potential threats. However, the love of your life often isn't a threat, and this response is usually linked to the production of oxytocin and dopamine, which are direct inducers of pupil dilation.

Quickening heart

When you feel physically or emotionally stressed, hormones called catecholamines are sent into the bloodstream. At the beginning of a relationship, people often feel nervous excitement before seeing their partner. In this higher emotional state, the hormones released are responsible for increasing your heart rate and can cause your senses to be on high alert.

Pain reduction

Love is sometimes referred to as a drug, as it can quite literally act as a painkiller. When thinking of or spending time with a loved one, changes occur in areas of the brain that are impacted by morphine and cocaine. These effects usually happen during the early stages.

Experiencing butterflies

Conjuring the romantic imagery of delicate fluttery creatures, the saying 'I've got butterflies' refers to the connection between mind and stomach instigated by love. Cranial nerves help link the brain to other areas of your body, and being the longest of these, the vagus nerve connects to the gut. To create this feeling the nerve triggers involuntary contractions in the stomach, caused by the brain's chemical response to nervousness. While it's not entirely known what the main purpose of this is as a survival mechanism, it could be the body's way of forcing out harmful toxins.

Sweaty palms

Through a combination of the hormones noradrenaline and adrenaline, your palms can turn into a clammy mess in nervous anticipation. Often you sweat when your body increases in temperature as evaporation works to cool you down. In these cases, your veins get larger. However, in the case of excitement or nervousness your veins constrict, as no cooling process is required. The built-up emotional stress that comes with seeing a love interest causes the body to prepare for a range of eventualities. Sweaty hands can increase friction, tactile sensitivity and skin toughness.

Lower blood pressure

High blood pressure can increase the chances of having a heart attack or stroke, so you could think of love as a health benefit. Although many see the early stages as particularly stressful at times, after falling in love people generally respond with less stress. Social bonds with a partner reduce stress, and with this comes a lower blood pressure.

Synchronisation

Observations of two people in love have shown that we subconsciously mimic those we are attracted to. Whether we turn our feet to face them or mirror their body language, this demonstrates the empathy and unity being created between two people, a little like a pair of dancers. In some cases couples in love have even synchronised their breathing rates naturally by being in each other's presence.

Love causes a mirror in body language

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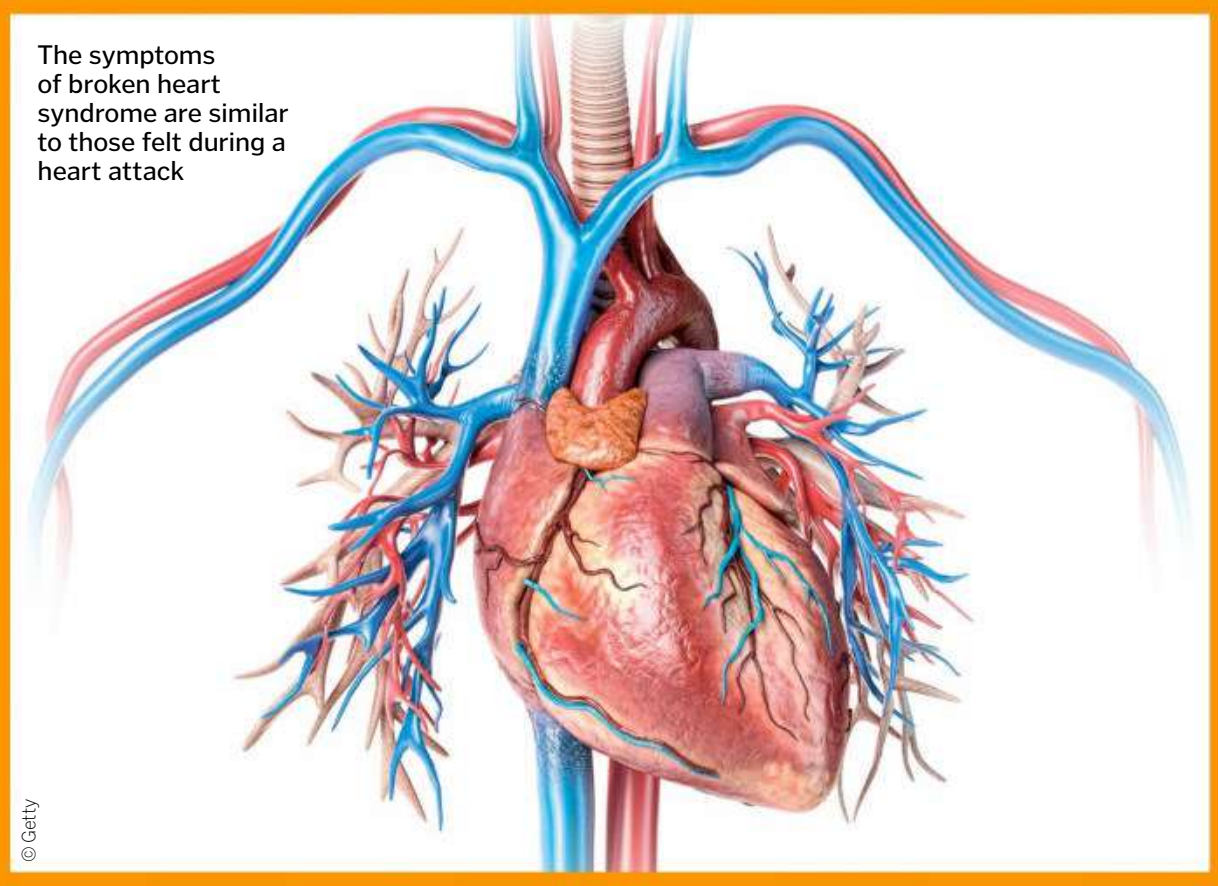


The symptoms of broken heart syndrome are similar to those felt during a heart attack

© Getty

Cases of a broken heart

Love can be the most uplifting feeling, flooding the body with feel-good chemicals and creating a strengthening bond of trust and infatuation. While these feelings can emotionally connect two people, it still doesn't change the fact that they are two independent bodies. Love can't be forced, and as many cases prove, it doesn't always last.

Heartbreak may be used to describe the emotional rollercoaster that is rejection, but broken heart syndrome is much more than simply feeling low; it's brought on by severe emotional trauma or a physical event of high intensity. While causes include some of the downfalls of love, such as divorce, infidelity, the death of a loved one and serious arguments, the syndrome isn't limited to love.

When the body is exposed to these situations, an influx of stress hormones take over. These are thought to cause the heart's main arteries to constrict in size, reducing the flow of blood in the heart. The effects of this usually include pain in the chest and difficulty breathing, but in a small number of cases this heartbreak can lead to death.

The science of monogamy

Of the 5,000 species of mammal on the planet, between three and five per cent are monogamous. This means that species that remain faithful to only one mate or partner are in the minority. So why do so many of us fall in love for life?

We are not as monogamous as some animals, such as geese, who may not mate for the rest of their life if their partner were to die. However, with a significant proportion of our population looking to 'find the one', what happens in our bodies to keep us going back to the same person? Oxytocin, the hormone often referred to as 'the love hormone', is responsible for strengthening monogamous relationships. Creating a bond to the person you have connected romantically with, the hormone is used to reward the brain. The more intense response created makes any interaction with that one person feel better than interaction with anyone else.

Marriage is traditionally viewed as a way to promise someone that you'll love them forever

© Getty

ALLOYS CUTTING-EDGE MATERIALS

How mixing metals has given humans tools to help shape the modern world

Words by **Andy Extance**

If you ever pick up an object made of or containing metal, more often than not it's an alloy. This underlines the little-known fact that alloys have been vitally important in making our lives today so comfortable.

Alloys are mixtures of chemical elements where at least one of the elements is a metal. Unlike the atoms in molecules like water, usually they are not chemically bonded together. Instead they just sit side by side. To mix metal atoms together in this way, someone must melt at least one of the metal components, which usually only happens at very high temperatures. That means alloys can be quite difficult to make – but the effort is worth it. Mixing two metals together can improve greatly on what each one can do on its own.

> *"Alloys are mixtures of elements where at least one of the elements is a metal"*

For example, most pure metals are fairly soft, and therefore no good for use in hard-wearing tools like hammers or knives. That's because the layers of atoms that form them can easily slide over each other. Mixing up atoms of different sizes can stop the sliding, as smaller atoms struggle to get around bigger ones. The smaller atoms slot into the gaps between the bigger atoms, making 'interstitial' alloys.

Sometimes different elements being mixed have similar atomic sizes, and one element just swaps in for atoms of the other type. These are called 'substitution' alloys.

Today we have a lot of useful alloys, but there may still be others to find. With more than 80 metals in the periodic table of elements – and scope to mix in non-metal elements – there are a lot of possibilities!

From meteors to spy planes

The first alloys that humans turned into tools and weapons came from space; people used iron and nickel mixtures brought to Earth's surface by meteors. Then, around 2500 BCE, someone mixed copper with tin to create bronze. The resulting alloy was much harder than its ingredients, and gave its name to the Bronze Age.

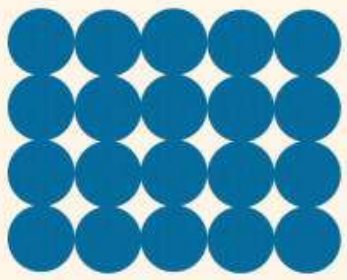
Since then we've invented even more alloys. In the 19th century removing impurities from steel made it reliably strong, starting the Industrial Revolution. After World War II, Russia and the US wanted faster, lighter spy planes. That led to scientists developing low-weight, high-strength titanium alloys.

© Getty

The Lockheed Blackbird SR-71 was a stealth aircraft built with lightweight titanium alloys

PURE METAL VERSUS METAL ALLOY

Metals mixed together can be more useful than they are on their own

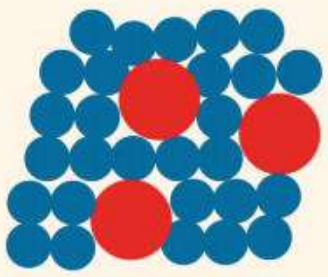


PURE METAL

Softness
Metals like gold and silver are relatively soft, making them easy to shape into jewellery, but no good for tools.

Low tensile strength
Aluminium foil is easy to tear because it has low tensile strength. To improve this, it can be alloyed with magnesium or copper.

Magnetic properties
Many metals are magnetic, but not always in useful ways. Mixing metals as alloys can improve that.

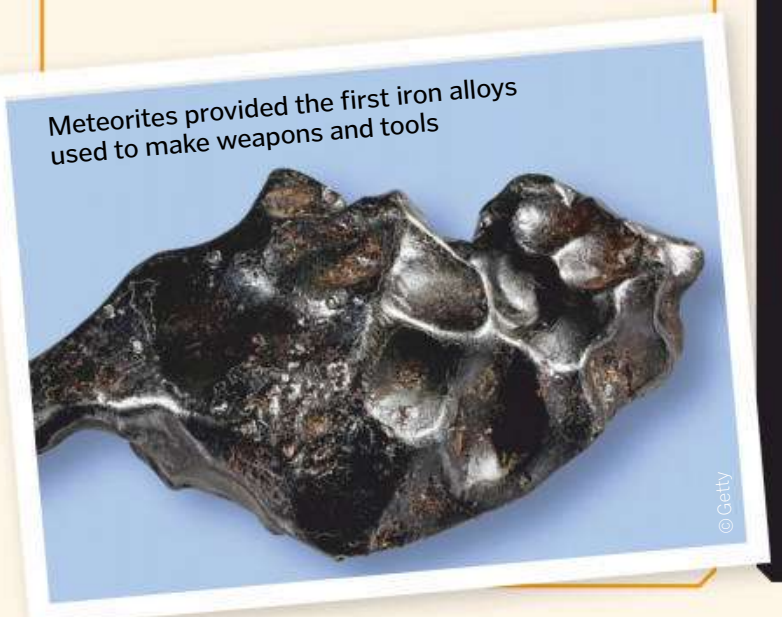


METAL ALLOY

Ductility
Alloys can be more ductile than the metal they're made from, meaning that it's easier to bend them and draw them out into long wires.

Hardness
Because the atoms in alloys don't slide around as easily, they don't move as much when something hits them.

Corrosion resistance
Iron rusts easily, but mixing it with carbon to make steel reduces that problem. Other alloys are even more corrosion resistant.



THE WORLD'S LEADING ALLOYS

Alloys are used in many objects in our homes – and sometimes even in our bodies

Amalgam
Dentists mix liquid mercury with a powder containing the other metals to make a soft putty, which quickly hardens to make strong, long-lasting tooth fillings.

= Mercury + Silver + Tin + Copper

Brass
Brass is a widely used metal alloy because it's easy to form into different shapes. It can be found in products ranging from cars to musical instruments.

= Copper + Zinc

Bronze
People first liked bronze because knives made of it stayed sharper than copper ones. It's still used today in heavy-duty machine parts, such as gears.

= Copper + Tin

Cast iron
With a high carbon content, cast iron melts at a low temperature, and is easy to make into products like kitchen pans and car parts.

= Iron + Carbon

Gunmetal
The name comes from the fact that gunmetal was once used to make cannons. Today it is used for intricate parts often found in plumbing, and also statues.

= Copper + Tin + Zinc

Pewter
Pewter is tin hardened by other elements, but can be shaped at relatively low temperatures. It was used for kitchenware, but today is mostly decorative.

= Tin + Copper + Lead + Antimony

Solder
Solder is mixed to make metals easy to melt. It then hardens as it cools. It joins electrical connections together, and so is very important.

= Lead + Tin

Stainless steel
The chromium in stainless steel forms an outer layer that helps stop the steel rusting. It's common in cutlery and has thousands of other uses.

= Iron + Chromium + Carbon + Molybdenum

Steel
Mixing iron with carbon makes it harder, and also reduces the chances of it rusting. Steel is vital in many industries, including building and car manufacturing.

= Iron + Carbon

Sterling silver
Pure silver is a very soft metal, so adding 7.5 per cent copper makes it stronger and therefore more suitable for producing practical objects like cutlery.

= Silver + Copper

All boxout images: Source © Wiki

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EXPLORING THE HIMALAYAS

How one collision created a diverse land of culture, ecology and the world's tallest point

Words by **Ailsa Harvey**

Covering close to 600,000 square kilometres, the Himalayas are a mountaineer's playground. With over 50 mountains exceeding 7,000 metres and home to ten of the world's 14 highest peaks, the choice and range of required skill sets provides a challenge for explorers of all abilities.

Some of the earliest people to venture into the Himalayas were traders and pilgrims. Like most who have visited the area, pilgrims took to the mountains in search of a test. Through religion, they saw the Himalayas as an environment of physical extremes. They believed that the more testing their pilgrimage was, the more worthy they became of salvation. And what place is more testing than the Himalayas?

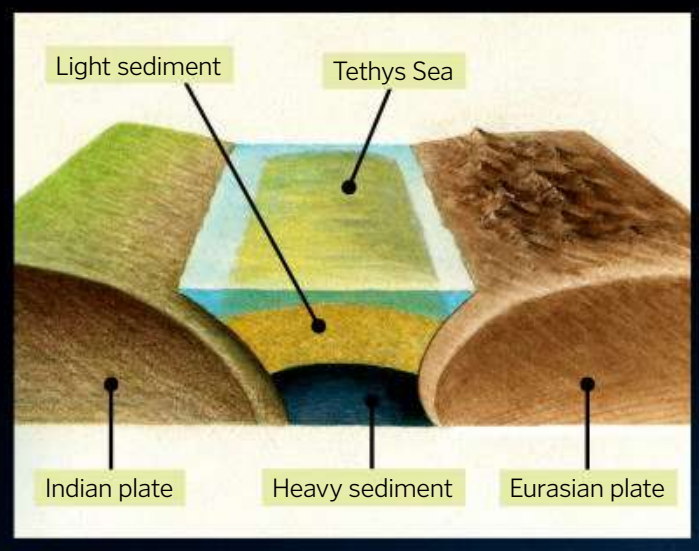
Divided into three geological zones – the Outer Himalayas, the Middle Himalayas and the Great Himalayas – the environment ranges from the tropics down below to the jagged peaks that cut into the clouds. Passing through five countries – India, Pakistan, China, Bhutan and Nepal – it is no wonder the Himalayas are so varied. The further down you explore into valleys shadowed by steep slopes, the more variety in life you'll find – from the mountain-dwelling creatures who have adapted to suit this unique environment to the settlements and villages below the snow line who live off the resources from the mountains.

Initially it was believed that the earliest human inhabitants lived in the area no earlier than 5,200 years ago. Now, however, evidence in the form of ancient footprints solidified into mud dates the start of mountain life between 7,400 and 12,600 years ago. While the high-altitude areas of the Himalayas are not the easiest places to live, at this time the region would have been more humid, and agriculture could have been better supported higher up in the mountains.

The climate continues to change to this day, shaping a new version of the Himalayas. With growing concern over the implications of global warming, nations surrounding the mountain range are working together to protect the land they not only admire, but depend on. More than 240 million people have made the peaks and crags their home, and amid the climate crisis are seeing some of the most dramatic impacts take a toll on it.

HOW THE HIMALAYAS FORMED

As an isolated island, 200 million years ago India started drifting in the direction of Asia. Millions of years later, its collision with the mainland would create the world's highest mountain range



1 60 million years ago

As India inched further north, the width of the Tethys Sea gradually decreased. When India reached Eurasia, a landmass of similar rock density, the sediment making up the Earth's crust felt an extreme force from both directions. Initially, because the two continental plates were of equal buoyancy, neither could push the other down underneath itself in a process called subduction. As the sea became narrower and pressure rose, the only option in relieving it was to throw the crust between them upwards.

2 40 million years ago

The heavier sediment at the floor of the Tethys Sea was able to force its way underneath the Eurasian plate over time. Meanwhile, India continued to push the base of the Eurasian plate, settling in position underneath it. The Indian plate kept moving, but slowed to half its original speed following the collision.

The king of the Himalayas

As the world's highest mountain, Mount Everest is at the top of many extreme explorers' lists. Others leave the peak of danger and uncertainty to the most daring and elite. As an attraction bringing hoards of tourists to the Himalayas, only a few make it to the summit. Every year since 1990, at least one person has died in pursuit of reaching its highest point.

The first official attempt to climb Mount Everest was in 1921 by a British team, but it wasn't until 29 May 1953 that the first mountaineers made it to the top – 8,848 metres above sea level.

Tenzing Norgay and Edmund Hillary climbed all the way up with the knowledge of the mountain's history of taking life. Of the few who had tried before them, many had not returned, but their adrenaline and desire to succeed overcame their fears. Since then about 5,000 people have climbed Mount Everest, and more than 300 people have died trying.

While a stunning spectacle looming over Tibet and Nepal, history tells of the extreme conditions on Everest. A combination of the human body's inability to cope with such altitudes, freezing conditions and the length of time exoposed to the elements over the distance travelled means there's an area of the Himalayas only the elite can successfully experience. Even then, the unpredictability of rock and ice falls, avalanches and earthquakes make for the powerful and unforgiving personality that is Mount Everest.

© Jamling Tenzing Norgay

Tenzing Norgay and Edmund Hillary photographed after climbing Everest

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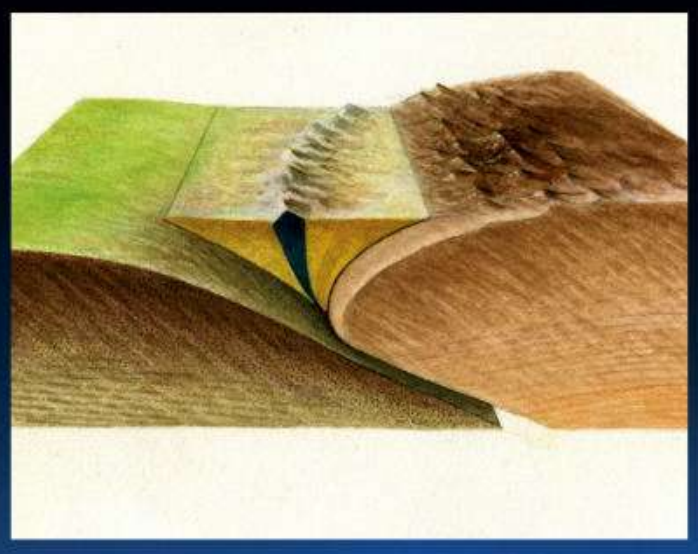
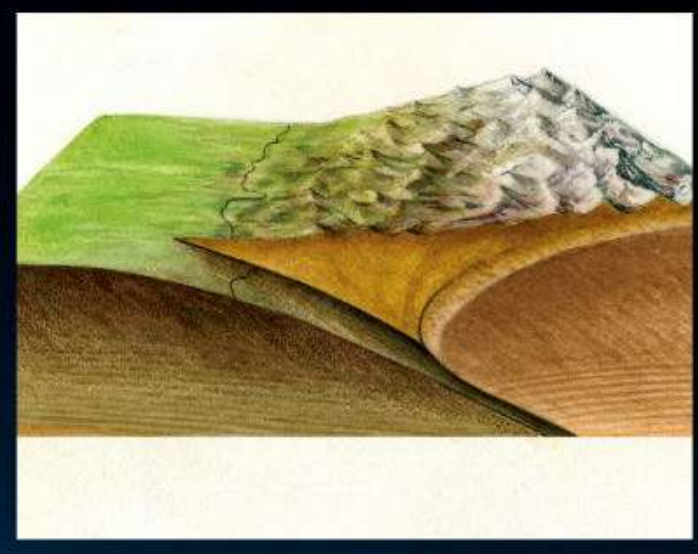


3 20 million years ago
After the Tethys' sea floor was forced downwards under the plates, only some heavy sediment remained. This sediment, wedged between the colliding plates, started to crumple upwards. This creased land was the early creation of the Himalayas, in place of the sea's disappearing water. Tibet, part of the Eurasian plate, began to rise with it.

4 Today
19-kilometres deep underneath the surface of the Himalayas, the Indian plate is still pushing northwards under the Eurasian plate. As the two plates continue to press against each other, the forces are pushing the Himalayan mountains marginally higher as every year passes.



© Illustration by The Art Agency/Sandra Doyle

5 10 million years from now
If the plates continue to move over each other at the current rate, Nepal's opposite borders will overlap each other, and the area where the country once was will no longer line up. As Nepal ceases to exist, the Himalayas – at the tallest they will have ever been – will be located near the Indian border.

Changing with the climate

Through studies of wildlife across the Himalayan landscape, it has been discovered that plants are surviving higher up the mountains than they were just 25 years ago. Between 5,000 and 5,500 metres, plants are testing the boundaries of where they can grow and are moving up the hills. In addition to plants, one of the most noticeable changes from global warming is the impact on snow and surface ice. As the planet continues to rise in temperature, snow and glacial ice will melt more rapidly and provide more areas suitable for plants to grow. This extra water will change what the area looks like, as well as the lives of those living in the foothills. Currently scientists are looking into the possibility of increased plant life acting as a catalyst in the warming of the Himalayas. Plants absorb heat and could change the way it is distributed across the land.

© Getty

Melting of Himalayan glaciers has doubled in the last 20 years

5 FACTS ABOUT HIMALAYAN LIVING

1 Himalayan inhabitants
50 million people live among the mountains, with a further 450 million living along the base.

2 Extra land
In a process called 'terracing', people often make steps in the mountainside to increase flat land area used for growing crops.

3 Dung patties
In some villages, yak dung is dried into patties and used as fuel for fires.

4 Nature appreciation
Today and historically, many communities living in the Himalayan mountains and foothills view their unique surroundings as their protector and provider of all life. Many living in harsh environments are also dependant on nature and greatly respect it.

5 Thriving tourism
Over 700,000 tourists travel to the Himalayas every year. This 60 per cent increase since the 1990s has provided locals with more jobs, but is also negatively impacting the environment through pollution and deforestation.

TOP 10 HIGHEST

Not only the highest in the Himalayas, but also the world: these mountains make up all but four of the planet's 8,000-metre-plus peaks

© Alamy

Everest South Base Camp, where many prepare for their climb, is 5,364 metres above sea level

© Wolfgang Byer

10 Annapurna I East, 8,026m

This mountain is the tallest in the Annapurna range and the tenth-tallest peak in the world. Annapurna is named after a Hindu goddess, whose name means 'filled with food'. With the huge mountain creating runoff water for much of the land below, it provides the ideal conditions for crops and food to be grown for the surrounding communities. The Annapurna mountain range has been a conservation area since 1985, becoming the largest protected area in Nepal.

9 Nanga Parbat, 8,126m

The name means 'naked mountain' in Urdu, due to the sides being so steep that snow often doesn't settle on much of it. Relatively young, the mountain is only 1 or 2 million years old. After the 31st mountain climber died attempting to reach the top, many in the community referred to it as the 'Killer Mountain'. This nickname has remained. The first attempt was an unsuccessful one, as in 1895 Alfred Mummery and his group set off into the unknown, never to return.

© Getty

8 Manaslu, 8,163m

The area of Manaslu – meaning 'the mountain of spirit' – covers six climate zones, from tropical to alpine and arctic. Situated in the Gorkha District of Nepal, the eighth-tallest mountain in the world has long ridges and valley glaciers. Because of the first ascent being completed by Toshio Imanishi and Gyalzen Norbu of Japan in 1956, some claim that the peak belongs to Japan.

7 Dhaulagiri, 8,167m

When discovered in 1808, Dhaulagiri was thought to be the world's highest mountain. While it is actually the seventh tallest, it remains impressive and unique. Soaring 7,000 metres over the Kali Gandaki Gorge and stretching across 30 kilometres in length, Dhaulagiri's main crest is home to several peaks. Of these, four reach heights above 7,600 metres.

© Getty

6 Cho Oyu, 8,188m

Found on the border between Nepal and Tibet, 32 kilometres north of Everest, sits Cho Oyu. While mighty in size, this mountain is relatively tame and is considered to be the safest of all the 8,000-metre peaks. With its fatality rate considerably low at one per cent, the climb is the most popular of the ten. The ascent on the north-facing side is deemed a gentle slope, which doesn't require too much technical skill. However, high fitness is crucial. In addition, avalanches are much less common.

5 Makalu, 8,485m

Taking fifth in the competition to be the world's tallest mountain is Makalu. Shaped like a four-sided pyramid, the mountain stands alone on the Tibetan-Nepalese border. The extreme and diverse terrain makes this mountain particularly dangerous. It's steep, and near the top rock climbing skills are required to move past the final ridge.

© Getty

4 Lhotse, 8,516m

When the top of Lhotse was first reached in 1956, it was merely a warm up to the main event; the climbers were using it as an alternative route to get to Everest. However, climbing this mountain is no easy feat. The fourth-highest mountain has two smaller peaks surrounding its main summit: Lhotse Shar to the east and Nuptse to the west. The west face near the top of this mammoth mountain has been claimed by many to be more challenging than Everest itself. Standing as a vast wall of blue glacial ice, choice of foot placement in this section can be the difference between making the summit or plummeting to your death.

3 Kangchenjunga, 8,586m

In the shape of a large cross, Kangchenjunga reaches outwards to the north, east, south and west. Structurally the mountain has five peaks, giving it its translated name of 'the five treasures of the high snow'. Consisting of rock up to a billion years old, the mountain has sacred value to many local Buddhists. Each peak is said to represent the five gifts from god: gold, silver, gems, grains and holy books. In the year 2000, the Indian state of Sikkim banned visitors from climbing the peak out of respect.

© Getty

2 K2, 8,611m

Also referred to as Mount Godwin-Austen after its early explorer Henry Godwin-Austen, this mountain resides in the Karakoram mountain range on the border of China and Pakistan. Around a quarter of the people who have attempted to get to its peak have died trying, earning it the nickname of 'Savage Mountain'.

For a year the mountain was incorrectly regarded as the world's tallest before explorers realised it actually measured more than 200 metres below Everest. While second highest in terms of height above sea level, it is classed as the 22nd most prominent mountain. Its point rises over 4,000 metres above the ground below.

© Getty

1 Everest, 8,848m

Reaching the top of Everest means reaching the world's highest point, and that point is still getting around six millimetres taller every year. Estimated to be between 50 and 60 million years old, the plates below it continue to move. This instability adds to the unpredictable nature of Earth's mightiest mountain, causing tremors, avalanches and earthquakes.

For humans the heights of Everest can be unforgiving. With a third of the air pressure found at sea level, oxygen deprivation is the greatest risk to life. Reaching minus 40 degrees Celsius in winter months, frostbite is another deadly prospect. What is it like to reach the top of the world? Most people who climb the mountain use one of two main routes, but there are 17 routes to take. The top of the mountain consists of a small, snowy dome, allowing only a handful of people to truly be on Earth's summit at one time.

ANIMALS OF THE HIMALAYAS

Yak

© Getty

Widespread across the Himalayan region, the yak is most similar to the cow or buffalo. Today the animal is mainly domesticated, and their strength is often used as a form of transport for goods across the mountainous land. Covered in long hair, yaks are adapted to live in cold climates at high altitudes.

Snow leopard

© Getty

These leopards are accustomed to the snowy regions of the Himalayas. If you can see past their camouflaged coat, they can be spotted high up in the mountains. One of their key characteristics helping them move swiftly on the area's uneven ground is their long, thick tail, used for balance.

Red panda

© Getty

The distinctive red panda is most common in the eastern areas of the Himalayas, such as Nepal, China and Bhutan. As the majority of their lives are spent climbing tree branches, this panda is found lower in the Himalayas where tree life is supported.

Himalayan monal

© Getty

The Himalayan monal, also known as the danphe, is Nepal's national bird. Vibrant in their rainbow feather display, these animals are like a cross between a pheasant and a peacock. Usually the birds can be seen among the trees and the shrubland between 2,100 to 4,500 metres high.

Himalayan black bear

© Getty

The location of this rare Asian black bear subspecies changes with the season. During the summer months they can adventure to heights of 3,000 metres, but come winter they remain at half this height in the more comfortable tropical areas of Tibet, Nepal, China and India.

Himalayan tahr

© Getty

The tahr have adapted to the steep rock faces of the Himalayas. Their dense coats change thickness with the temperature and their flexible hooves make them better climbers than similarly built goats. Unfortunately these animals have suffered a loss in numbers due to hunting and habitat loss from increased human population.

Why flies buzz

It's this persistent hum that alerts us to their presence, but what makes these tiny insects fly with such a racket?

You'll usually hear them before you see them. Acting like a warning seconds before appearing in front of your face, flies carry a distinctive, high-pitched buzz that resonates as they fly. Equipped with wings, flies are able to occupy niche environments out of reach of flightless life forms.

Small in comparison to the world's other airborne animals, these insects need to move their delicate wings at rapid speeds. The flapping you hear when birds fly is replaced with a much higher pitched buzzing noise. Able to trap significantly less air under their wings having little surface area, a quicker movement is needed to keep their bodies in the air.

What is the purpose of a fly buzzing during this process? It appears that this noise is simply a by-product of the energy exerted in flying, but for some species of fly there is more to their buzz. Whether it's a form of communication or an escalating warning signal – as seen in hoverflies when danger encroaches – some insects have more control over these persistent sounds than it may appear.

Musical mosquitoes

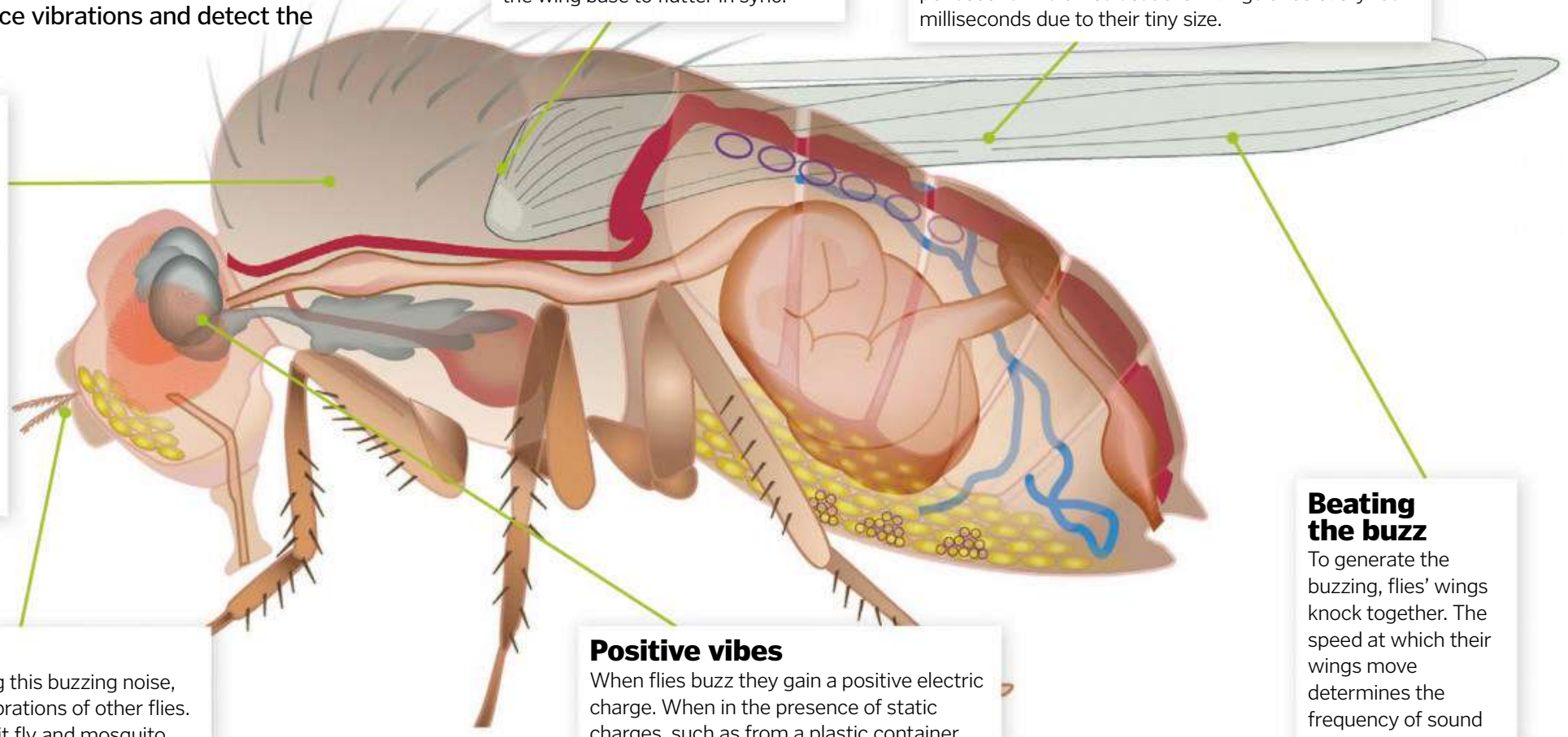
You might not recognise its sound, as by the time you feel a bite, the mosquito has flown away. However, they all have their own individual buzz. When mosquitoes encounter each other, they can tell the difference between each of their sounds. While we may only hear a subtle difference – if any – the flies themselves depend on these differences and use the buzzing as a form of communication. One use for mosquitoes' buzzing is to seduce a mate. In a strange form of fly flirting, if one copies the tone of the other, it's a match.

In what is referred to as 'harmonic convergence', mosquitoes adapt their frequency to hum a duet with potential mates

© Alamy

Fly anatomy

The body of this fruit fly is engineered to help it take flight, produce vibrations and detect the sounds of others



Connected structure
The thorax is linked to the base of the wings. When the body of the fly contracts, the connection causes the wing base to flutter in sync.

Fast flappers
Most flies can flap their wings at speeds of 200 cycles per second. Fruit flies beat their wings once every four milliseconds due to their tiny size.

Thorax
In some flies the middle section of a fly, known as the thorax, constantly vibrates during flight. These flies bypass the method of contracting specific muscles attached to the base of the wings and instead shake the entirety of the wider area.

Beating the buzz
To generate the buzzing, flies' wings knock together. The speed at which their wings move determines the frequency of sound waves and the pitch released.

Hearing
As well as producing this buzzing noise, flies can hear the vibrations of other flies. Flies such as the fruit fly and mosquito detect noise through the vibrating movement of their antennae hairs.

Positive vibes
When flies buzz they gain a positive electric charge. When in the presence of static charges, such as from a plastic container, wing movements are disturbed, resulting in an imbalance of chemicals in their brains.

Insect harmonies

We often refer to anything buzzing past our heads simply as a 'fly', but there are in fact over 150,000 species of fly around the world. The larger the fly, the louder the buzzing sound will be heard. The noisiest species of fly are blowflies, which hit their wings together 150 times a second. Producing a higher frequency than the average house fly, blowflies' larger wings disturb more air during flight.

The number of wings a flying insect has also changes the resulting buzz sound. A true fly only has two wings, but similar insects such as bees have four. Having more wings means that they don't need to be flapped as quickly for the same lift. This lower frequency results in a deeper buzz, while flies' frantic movements create the higher pitch that many people find less tolerable.

Fly species have different dialects. Fruit flies converse to alert others to parasitic wasps

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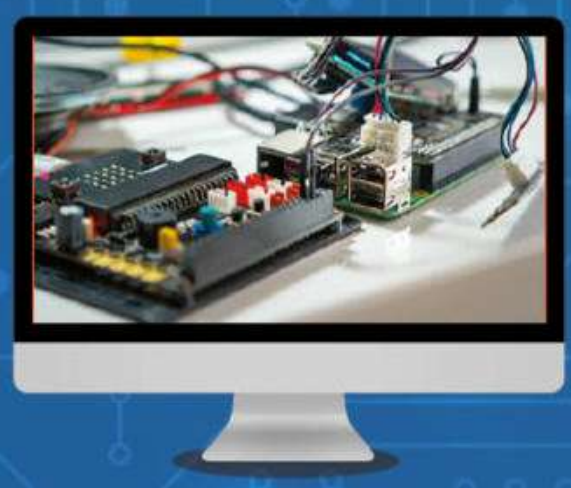

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Preventing vehicle theft

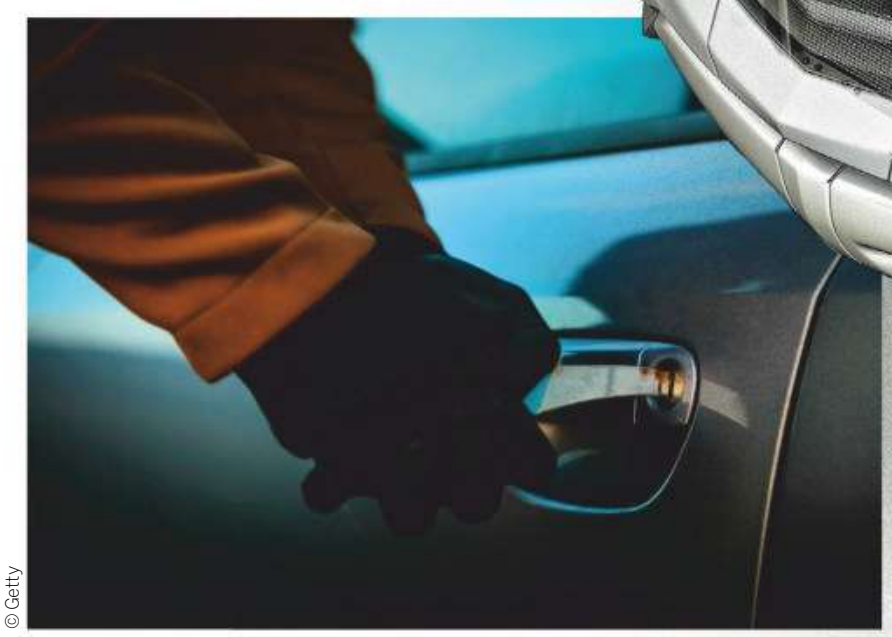
These anti-theft features can help protect your car where you park it

For as long as cars have been around, methods to protect them from car thieves have been necessary. Many of us rely on our vehicles, spending so much time travelling in them that they become extremely personal to us. The first car locks were only made available to the wealthiest of drivers, and only focused on the security of doors. Today, however, every part of a newly manufactured car is equipped with devices and systems that will provide security for the car's owner.

In an increasingly digital age, new car mechanisms that add ease and comfort to driving are also giving thieves new methods to steal cars – and security systems need to keep up.

This is where identity-driven security will help, making it harder for digital hackers. The introduction of facial, voice or thumbprint recognition make the requirements for access much more specific. To keep digitised car systems secure, a relationship needs to be established between you and your car. This means that if an intruder enters the car, they are not recognised as the car's legal owner, and thus can't access the controls.

Using facial recognition, the car remembers the measurements of your features and compares these to its database. If the wrong face tries to start the car, the computer will know that the person doesn't have access and the system remains locked. We are still a long way away from unconquerable car security, but in the meantime new cars are more secure than ever with these modern security devices.



© Getty

Pressure sensors monitor irregular forceful actions during break-ins and send a signal to set off the alarm

Alarm

Car alarms are one of the most common ways to protect a car, deterring criminals and alerting the owner. Some of the earlier car alarm systems only had one or two sensors, but modern designs are equipped to detect up to ten types of threat. With a computer at the centre, car alarms are designed to sound the loudspeaker for multiple threats. Door sensors set off the alarm when access is granted without the key, shock sensors alert to damage created from impacts, microphones hear loud break-ins and tilt sensors stop cars from being towed away.

Dash cam

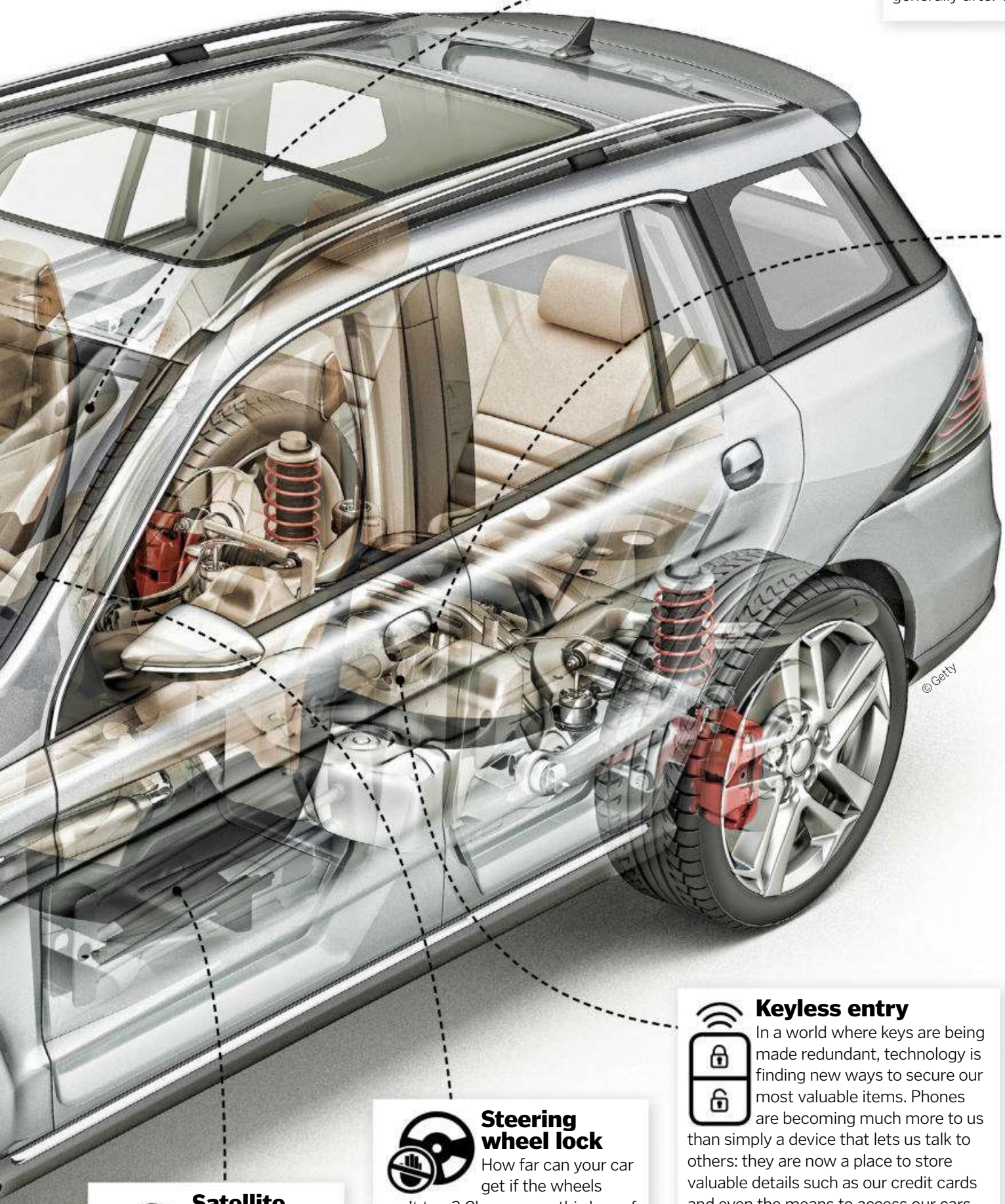
Cameras located on the dashboard can act as digital eyes, holding people accountable for their actions. Surveying both inside and outside the car, the footage can be recovered from the camera or streamed to a smart device. Dash cams are continuously evolving with advances in photographic technology. Today you can purchase a camera that detects movement and automatically starts recording, as well as an automatic time-lapse setting that lets you view hours worth of action in a matter of seconds.

Immobilisers

Even if a thief can find a way to break into your car, this is of no benefit to them if they can't get the car to drive. Immobilisers are handy devices that cause the engine to shut down when the correct key is not present. The electronic circuit inside your key or key fob sends a code to the electronic control unit (ECU). Only if this code matches that in the ECU does the engine start up.

What makes a vehicle secure?

Take a look at a modern car's core security features that stop thieves in their tracks



Vehicle Identification Number (VIN)

Each car has a unique VIN. This number is often etched into the windscreen of your car, making it less valuable to a thief. They are less likely to steal your car to sell on as it can be easily identified as a stolen car. To sell it on, they would have to replace the glass, which is more hassle than it's worth. Car thieves are generally after the highest profit for least effort.

Double-locked doors

You might have noticed that to get out of your locked car from the inside you do not need a key. If this is the case, your car uses single locking. While this stops anyone from opening the car using the handle on the outside, it means that by smashing the window and reaching in, they can gain entry to the vehicle. Double-locked doors prevent the opening of the doors on both sides.

Keyless entry

In a world where keys are being made redundant, technology is finding new ways to secure our most valuable items. Phones are becoming much more to us than simply a device that lets us talk to others: they are now a place to store valuable details such as our credit cards and even the means to access our cars. Smartphones now have the ability to show us whether our car is locked at all times, so there is no more panic asking yourself if you're sure that you locked your car. Cars can be unlocked and locked at the touch of a phone screen, and some automatically unlock in the presence of your mobile. The only downside is that digital keys can let hackers in. Voice recognition and face recognition are deemed secure by car companies such as BMW and Ford. As everyone has a unique face and sound to their voice, these could be as secure as – if not exceeding – the traditional key.

Steering wheel lock

How far can your car get if the wheels can't turn? Chances are this loss of function will make driving it away a lot more difficult. Fitted onto the steering wheel, these locks mean that without authorisation, the car can't be steered. Though they have been around for a while and can be bulky, some people prefer this traditional method as a way to reduce the likelihood of hacking found in the digital world.

Satellite tracking

In the event that all other security measures fail and your car is missing, the car can be tracked down using a GPS tracker, installed under a seat. The car will send a signal to orbiting satellites, which will relay the location of your vehicle to a smart device. Usually presented in a map format, you will be able to see the speed the car is travelling – and, most importantly, where it is.

How to stop digital hackers

We have relative control over the security of our car keys. If we keep them somewhere safe or on our person, the chances of someone else getting hold of them are slim. However, with cars becoming increasingly computerised, how do we stop people breaking in using digital means? Is there anything we can do to protect the car's digital computer system in the same way?

More cars are doing away with physical keys altogether, using a wireless signal from the key fob instead. Some thieves steal cars by amplifying the signal from the contactless fob. This tricks the car into thinking the device is nearby – but you can trick the hackers. By placing the key fob in the fridge or a Faraday bag – a pouch that shields anything inside from some electromagnetic wavelengths – the thieves' signal is blocked and they can't use it for access. Additionally, making sure software is up to date, just as you would on your computer, prevents bugs that hackers can use to find your personal and biometric data that could give them access to the car.

The internet of things is an online, interconnected communication platform for devices that hackers can manipulate to gain entry to modern vehicles

While riding a wave lift, paragliders can reach heights of around 10,670 metres

© Shutterstock

How to fly a paraglider

Discover how these seated parachutes steer in the sky and ride the airwaves

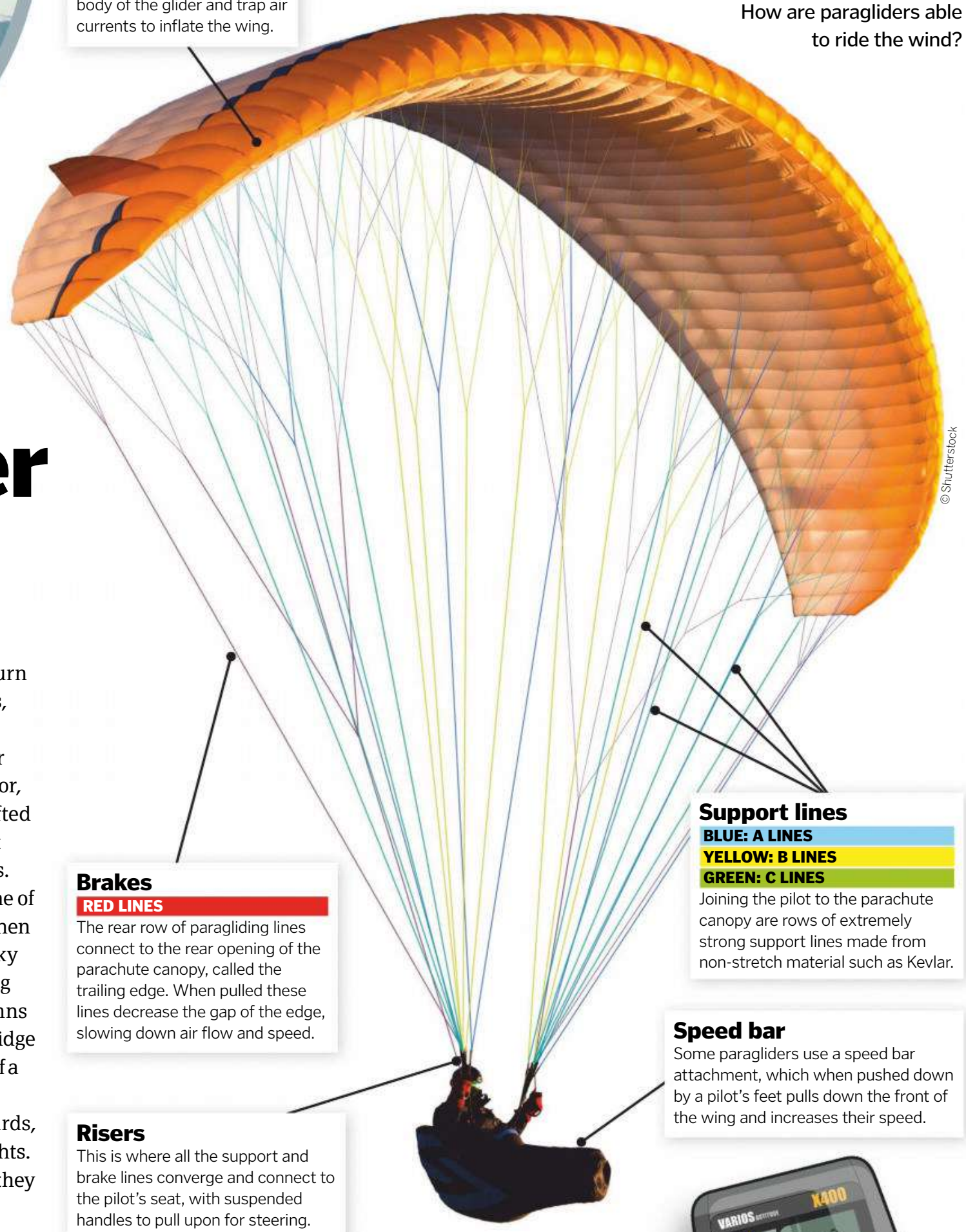
Born from the military, designed to return pilots safely to the ground in the 1960s, parachutes were quickly adopted by thrill-seekers to ride the winds. However, far from their simple stringed parachute ancestor, modern-day gliders have been carefully crafted to utilise air currents to not only create a soft landing, but as a way to ascend into the skies.

Rideable air currents are categorised in one of three ways. The first, 'thermal lift', occurs when the Sun heats a patch of land, typically a rocky area, which in turn expands the surrounding air, causing it to rise and form thermal columns that paragliders can use to stay in mid-air. Ridge and wave lift both occur on opposing sides of a mountain. As air currents collide with the mountain face, the currents are forced upwards, allowing paragliders to climb to higher heights. As the currents cascade over the mountain, they almost bounce off the surrounding ground, potentially creating even higher lifts.

To tame the air currents, paragliders apply simple physics. As air flows through an opening in the glider called the 'leading edge' and flows out through the 'trailing edge', pilots pull on either one of the hanging control handles for the corresponding direction they wish to turn. For example, in attempting to veer to the right, by gently pulling on the handle on their right, the connecting line will change the shape of the glider, decreasing airflow on the right and turning the glider in that direction. Steering in the sky can also be as simple as shifting your body weight to the desired direction.

Steering through the sky

How are paragliders able to ride the wind?



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Cells

To maintain flight, rows of ripstop nylon cells form the body of the glider and trap air currents to inflate the wing.

Support lines

BLUE: A LINES
YELLOW: B LINES
GREEN: C LINES

Joining the pilot to the parachute canopy are rows of extremely strong support lines made from non-stretch material such as Kevlar.

Brakes

RED LINES

The rear row of paragliding lines connect to the rear opening of the parachute canopy, called the trailing edge. When pulled these lines decrease the gap of the edge, slowing down air flow and speed.

Speed bar

Some paragliders use a speed bar attachment, which when pushed down by a pilot's feet pulls down the front of the wing and increases their speed.

Risers

This is where all the support and brake lines converge and connect to the pilot's seat, with suspended handles to pull upon for steering.

In-flight essential

Sailing solely on the force of air currents using a non-motorised paraglider can keep you aloft for around three hours from launch. During that time it's difficult to keep track of your proximity to the ground or the speed you're gaining altitude at based on natural perception alone. This is why paraglider pilots use a handheld tool called a variometer to monitor their altitude and the speed at which they are climbing and falling. The variometer uses air pressure sensors, and in some examples GPS, to indicate the pilot's vertical speed. Digital variometers will begin to sound a beeping alarm when a pilot's vertical speed is too fast to prevent the wing from becoming uncontrollable.

© Getty

Variometers are most commonly used when navigating a thermal column

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HERE COME THE SELF-MANAGING ROBOTS

Bristling with modern tech, tools, and a brain to boot – these are the smart machines that could change the way we live

Words by **Mark Smith**

© Wyss Institute at Harvard University

EMERGENCY ROBOT

Steel hero that fears no flames

How do you tackle a blaze that's too ferocious for a human firefighter to go anywhere near? Easy, just send in a robot firefighter instead!

Mitsubishi Heavy Industries in Japan has crafted a team of robo firefighters that combat industrial fires, working together just like human firefighters do.

Each one comes equipped with laser sensors and GPS so they can find their way to the fire. Once there the Hose Extension Robot brings the super-long hosepipe to another robot that has a huge water cannon. It can then unleash its payload and squirt up to 4,000 litres a minute!

It may sound like science fiction, but this team of robots is already up and running, and has been tested at Tokyo's Research Institute of Fire and Disaster.

If robots like this keep proving their worth, how long before TV's Fireman Sam gets a metal replacement?

© Courtesy of Mitsubishi Heavy Industries

MITSUBISHI FIREFIGHTER

Weight (kg)	1,600kg
AI rating	3
Agility	1
Cool gadgets	5

Mitsubishi Heavy Industries' firefighting robot is designed to tackle tough industrial blazes

SPACE ROBOT

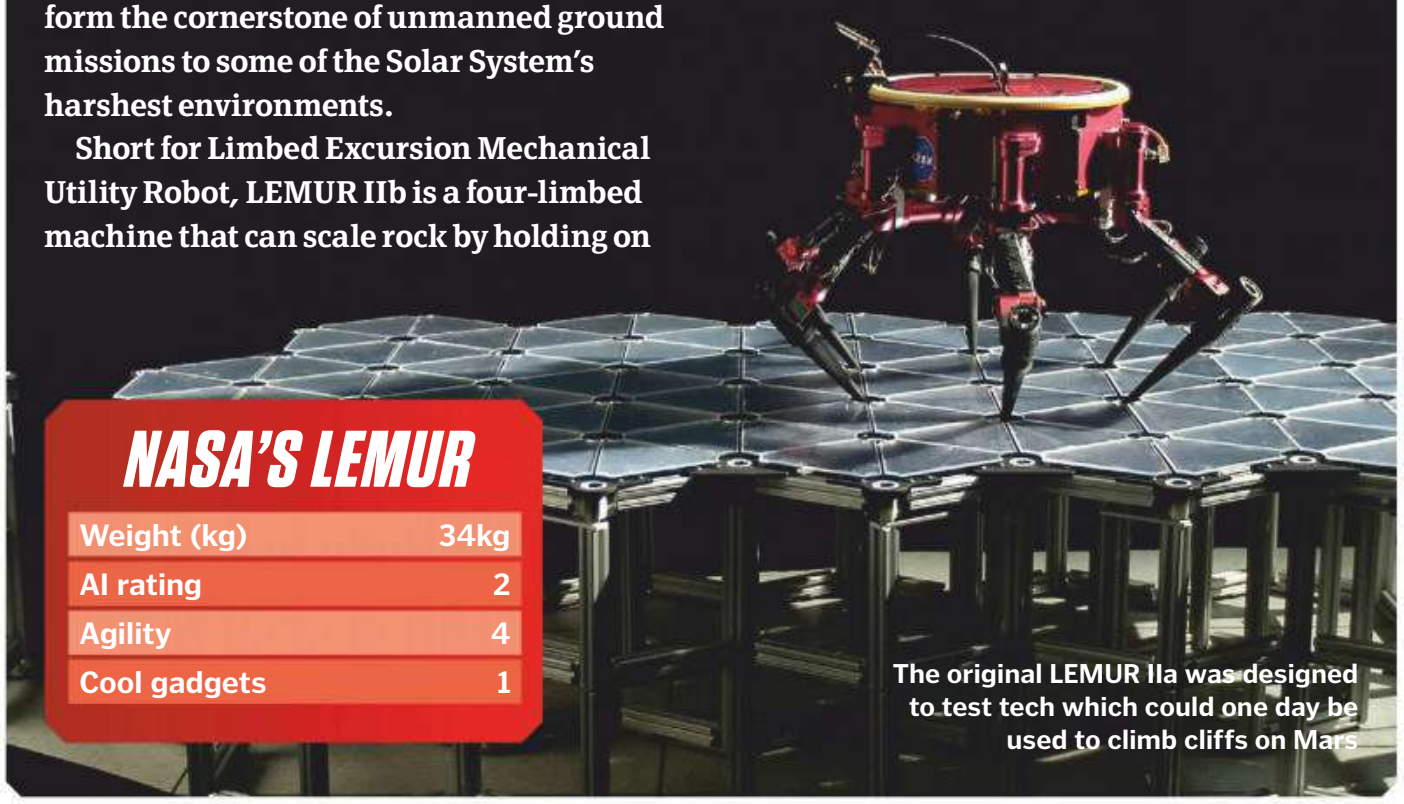
Space robot designed for climbing

Imagine a robot that could scale the craggy cliffs of the Martian wastes? That was what NASA scientists at its Jet Propulsion Laboratory had in mind when they put their LEMUR robot together.

Although this mechanical astronaut is yet to make it into space, the equipment that scientists tested on it could one day form the cornerstone of unmanned ground missions to some of the Solar System's harshest environments.

Short for Limbed Excursion Mechanical Utility Robot, LEMUR IIb is a four-limbed machine that can scale rock by holding on with hundreds of tiny hooks in each of its 16 fingers.

Engineers trialled the robot on a field test in California's Death Valley. During the mission it used artificial intelligence to choose a route up a cliff, managing this without the need to take instructions from its human controllers.



© NASA

NASA'S LEMUR

Weight (kg)	34kg
AI rating	2
Agility	4
Cool gadgets	1

The original LEMUR IIa was designed to test tech which could one day be used to climb cliffs on Mars

MEDICAL ROBOT

Da Vinci turns robo surgery into an art form

© Surgery_Robot

The pressures on the health service are well known. Medical staff are hard to train and are frequently under immense pressure, so what if we could have an unlimited army of artificial medical staff to help them out? The da Vinci robot is controlled by a surgeon via a special panel and comes equipped with surgical arms and a 3D high-definition camera so doctors can view the part of the body being operated on in high detail.

THE DA VINCI ROBOT

Weight (kg)	100kg
AI rating	1
Agility	1
Cool gadgets	5

AR ZONE!

MILITARY ROBOT

The robot that moves just like we do

This techno-marvel has arms and legs just like a human that it can use to walk and lift, run and jump. It's agile, strong and tough, and in its most recent tests it could perform a handstand, roll around and do a few jumping twists all without losing its balance.

This truly formidable robot is built around a mobile hydraulic system that packs motors, valves and a compact hydraulic power unit. Its 28 hydraulic joints allow it to perform truly impressive feats of mobility.

But its brains are just as impressive as its brawn. Complex algorithms allow it to make decisions so it can plan out how it's going to traverse specific obstacles.

In terms of construction, Atlas uses 3D-printed parts to give it the strength-to-weight ratio necessary for leaps and somersaults.

Currently being used as a research platform by Boston Dynamics in the US, once fully operational it could be used for search-and-rescue and military operations.

Smart character
Algorithms help the robot make decisions about how to tackle obstacles.

With its AI brains and hydraulic body, Atlas is the real deal

Strong arms
The robot is capable of lifting heavy weighted objects, making it ideal for rescue operations.

Printed parts
The robot is put together from a collection of 3D-printed parts.

Heavy hitter
This robot is no lightweight. Atlas weighs in at a hefty 80 kilograms.

Agile acrobat
Atlas features a range of internal devices to enable it to stay agile.

Cool runner
Powerful legs on the robot enable it to jump, walk, run and climb just like a human can.

Hydraulic power
Atlas comes equipped with 28 hydraulic joints designed to let it adopt a range of positions.

Bipedal machine
With two arms and legs, the Atlas robot can move the way a human can.

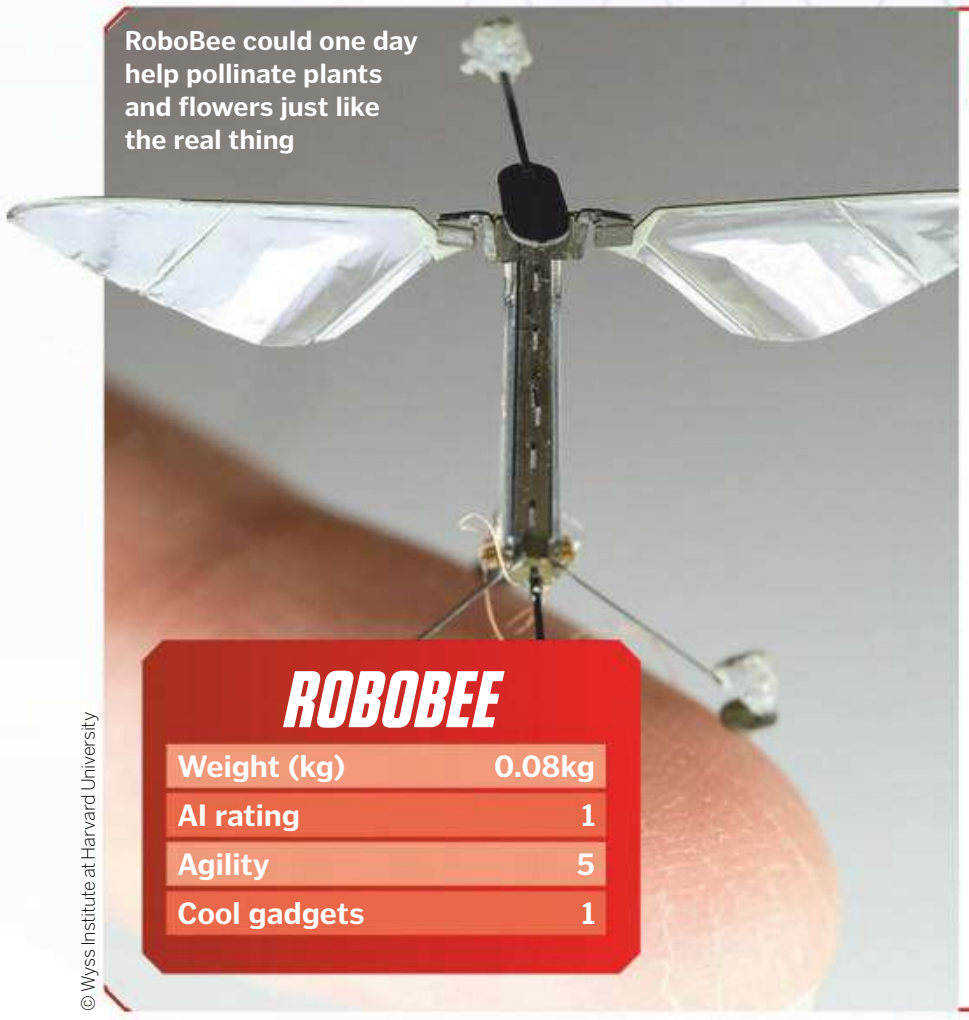
BOSTON DYNAMICS ATLAS

Weight (kg)	80kg
AI rating	5
Agility	5
Cool gadgets	4

AR ZONE! SCAN HERE

© Illustration by Nicholas Forder
© Boston Dynamic

DID YOU KNOW? *The RoboBee features two thin wings that flap 120 times per second*



RoboBee could one day help pollinate plants and flowers just like the real thing

© Wyss Institute at Harvard University

ROBOBEE

Weight (kg)	0.08kg
AI rating	1
Agility	5
Cool gadgets	1

ENVIRO/FARMING ROBOT

RoboBee is ready for action

The robot world is abuzz with excitement about the automated critters being constructed in the United States. Scientists at the Wyss Institute at Harvard University have designed these awesome robotic bees inspired by nature's finest purveyors of honey. Each RoboBee measures about half the size of a paper clip, weighs less than a tenth of a gram and flies using artificial 'muscles' made of materials that contract when a voltage is applied.

They could one day be used in search-and-rescue and even surveillance missions, but with real bee numbers dwindling, it's their potential for pollination that will have scientists most excited.

"They could one day be used in search-and-rescue and even surveillance missions"

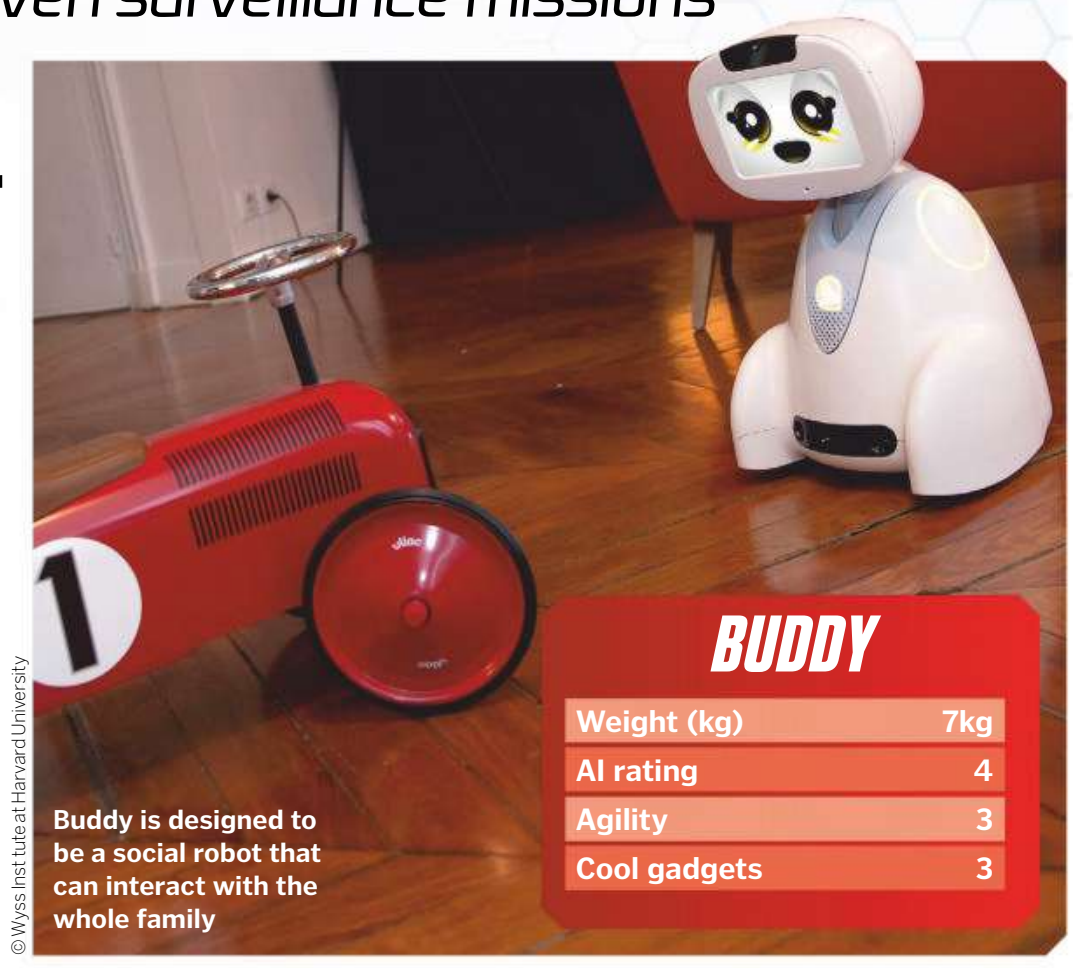
HOME HELP ROBOT

A new member of the family?

With the likes of Alexa and Google Home, our homes are increasingly filled with artificial assistants that feel like an important part of the family – but while they can talk to us, they can't actually move. Buddy, however, can.

Designed as a 'social robot', he comes complete with a range of features that enable him to move and interact with everyone.

The kids can play games with him, he can display emotions and can even connect to your smart home devices.



© Wyss Institute at Harvard University

Buddy is designed to be a social robot that can interact with the whole family

BUDDY

Weight (kg)	7kg
AI rating	4
Agility	3
Cool gadgets	3

Best of the rest

SPOT
Boston Dynamics' Spot has four legs, walks just like a dog and is being used for surveys in the oil and gas industry.

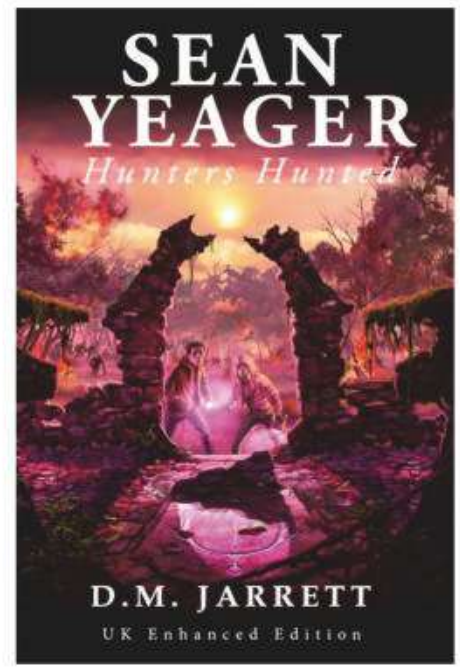
GUNDAM
Japan has built a 20-metre robot. The world's biggest machine of its type weights in at a whopping 25 tonnes.

ROLLBOT
The quirky RollBot can bring toilet paper to those stuck in compromising positions who've run out of loo roll.

KURI
Kuri is designed to react to sound, touch and has a lighting system to let you know what mood it's in.

VYOMMITRA
The Indian Space Research Organisation (ISRO) has unveiled its newest astronaut: a half-humanoid robot.

Androbots: neighbours controlled by alien parasites



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How a shotgun shoots

Everyone knows this classic field sports firearm – but few people realise exactly how these guns load and shoot their ammunition

Words by **Mike Jennings**

Shotguns are popular weapons for sport shooting – like the kind seen in the Olympics

© US Army

© Getty

Break-action shotguns need to be hinged open to be reloaded

Shotguns are some of the most familiar weapons on our screens thanks to their popularity in films and on TV shows. They're popular in the real world too, because they're powerful and versatile options for a whole range of scenarios. Shotguns are ideal for aiming at small, fast targets – like the devices used at clay shooting ranges – because the pellets they shoot have a wide spread, which means you don't have to aim quite so precisely.

These powerful guns have downsides too. Shotgun pellets aren't great at penetrating targets, and they don't have a huge range. If that's the kind of weapon you need, a rifle is far more effective. A shotgun's short range and wide spray means these devices are popular for the kind of shooting included in the Olympics, and they're also used by police and soldiers.

Break-action shotguns are the classic weapons in Westerns – the guns with a hinge between their barrel at the front and the stock at the back. The gun has to be opened in order to reload, which makes them quite slow.

A pump-action shotgun is more common in modern TV shows and movies – they have the handle underneath that can be aggressively pulled backwards to reload the weapon.

A semi-automatic shotgun does all of the reloading for you, so there's no messing with hinges or handles. They're faster, but they have more parts that can malfunction.

No matter what kind of shotgun used, the firing principle is the same: pulling the trigger ignites the small explosive primer on the shell. That creates gas that rapidly expands, which pushes the bullet through the barrel at increasing speeds. Once the bullet has been fired, the casing stays behind to be ejected – which leaves the crucial part of the shotgun shell travelling towards its target.

Pump-action particulars

Pump-action shotguns are among the most popular modern weapons – here's how they fire and reload

1 Firing squad
When the trigger is pulled, the firing pin is propelled upwards to start the ignition process by igniting the gunpowder in the cartridge.

2 Bite the bullet
Once the slug or shot has left the casing, the bolt and extraction mechanism pull the empty casing backwards to make space for the new cartridge.

Rifling through history

Weapons like shotguns have been used around the world for hundreds of years. Muskets, which have a similar structure, were being used way back in the 16th century. The term 'shotgun' was coined in the Wild West. As technology developed, these weapons became more refined. Models appeared with thinner barrels, so smaller and more precise ammunition could be used. A technique called 'rifling' was also developed. This method creates groves on the inside of the barrel which makes bullets spin as they're fired – this makes them more stable in the air, and therefore more accurate. As time went on these narrower, precise designs branched off into their own category, called rifles. Shotguns remained as more powerful short-range weapons.

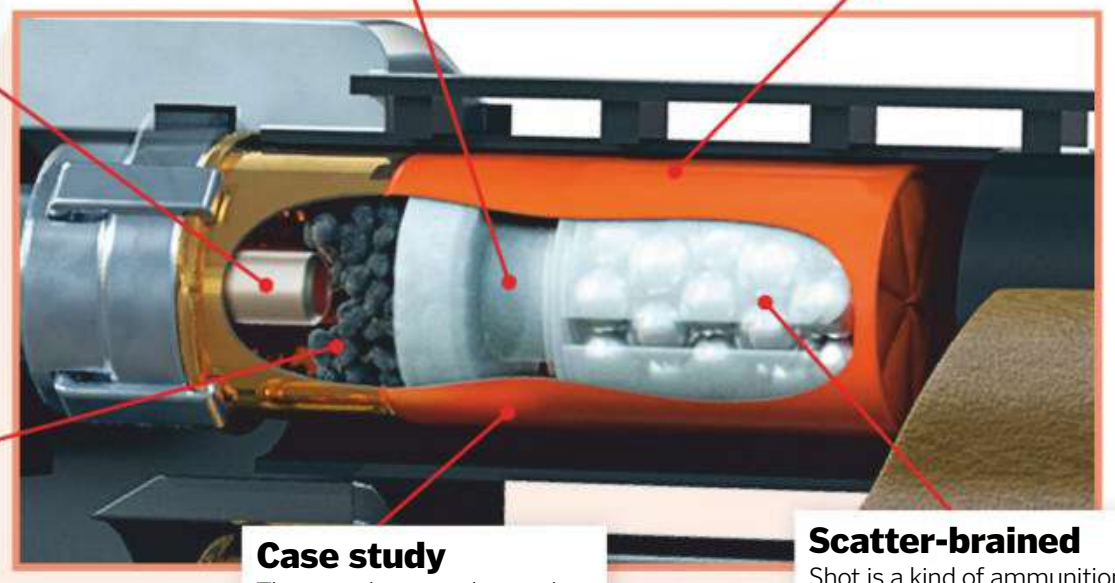
Shotgun secrets

Want to know exactly what's in a shotgun shell? Join us for an exploration of shotgun ammunition

Sealed gas
The wad sits in the middle of the cartridge, sealing the gas behind the bullet to make sure it's propelled properly.

Straight to the point
A slug is one kind of bullet available for shotguns. It's a single, larger projectile designed to hit one target.

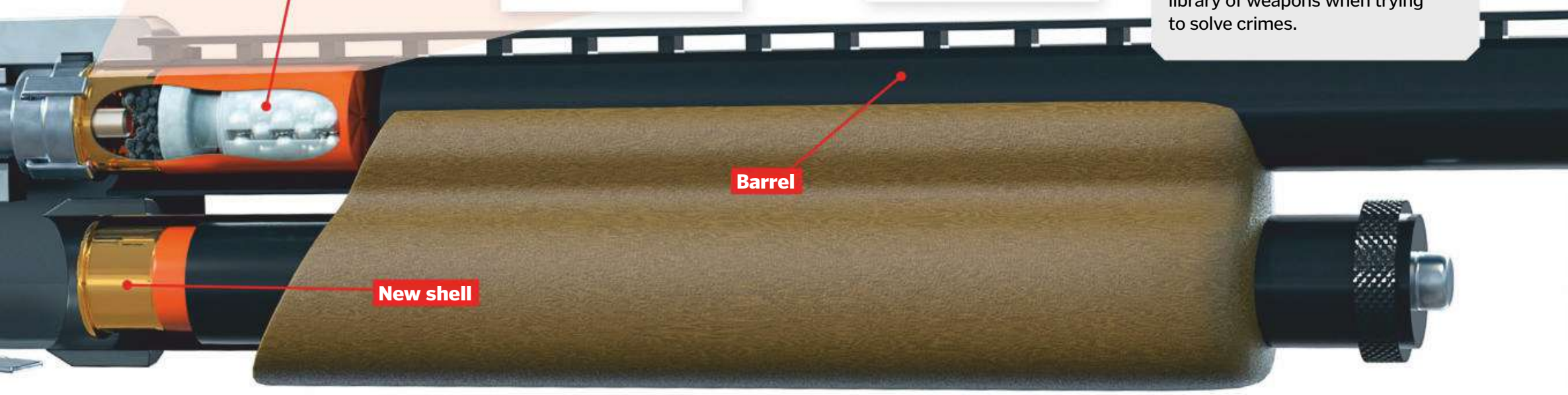
Firestarter
When the trigger is pulled, the firing pin strikes the primer, which explodes – igniting the gunpowder above.



Keep your powder dry
The firing process accelerates here – the gunpowder ignites, creating rapidly expanding gas that shoots the bullet down the barrel.

Case study
The outside casing keeps the bullet together, but it is removed from the barrel once the bullet has been fired.

Scatter-brained
Shot is a kind of ammunition made from smaller balls that scatters when fired to hit a wider spread of targets.



3 New shell
At the same time, pulling the magazine towards the user releases another shell beneath the barrel – ready for the next shot.

4 Ejector seat
The spent cartridge is ejected from the rear of the weapon, which also pulls the extractor backwards – creating a space for the new cartridge.

5 Lock and load
The next cartridge is bumped upwards into the chamber, and the springy extraction mechanism shoots forward to hold it in place.

6 Spring-loaded
The springy mechanism has returned to its starting point – ready to ignite the next cartridge and eject it again.

5 FACTS ABOUT SHOTGUN SURPRISES

1 A taxing affair
In the US, all sorts of guns are taxed heavily, with proceeds from shotgun and other firearm sales contributing to wildlife conversation and protection.

2 The bear necessities
Russian astronauts used to take guns into space in case they landed back on Earth and bears or other unfriendly wildlife was lurking nearby.

3 On your marks
Guns are used for races at athletics events because they fire incredibly quickly – human brains can't react at the same speed, so anyone matching the gun's pace must be cheating.

4 Trailblazers
The oldest gun manufacturer in the world is Beretta, which was established in Italy way back in 1526 and has been trading ever since.

5 Problem solving
The FBI keeps a stock of virtually every gun ever made so its agents can refer to the library of weapons when trying to solve crimes.

© Illustrations: The Art Agency/Barry Croucher

Luggage padlocks are often used to connect suitcase zips, keeping contents safe while travelling

© Getty

Anatomy of a padlock

These mechanical locks give you peace of mind, but how do these small metal devices keep your belongings secure?

Most of us leave the doors to our houses locked, feeling a sense of assurance that our cherished items are protected. But what about when you are in public? How can you keep your valuables out of reach from strangers without having to keep them on your person? This is where padlocks come into play.

From the tiny padlocks keeping the pages of diaries private to bulky, reinforced locks keeping iron gates secure, they're as popular today as they've ever been. This compact and intricate system is used to attach two items together, such as a door and a frame, two ends of a chain or a chain and a fixed frame.

These portable security devices have served us for longer than you may think. The first padlocks appeared in ancient Egypt, before becoming more advanced for various uses and widespread across the world. Some theories suggest that the 'pad' from the name means 'gate', and that early forms of padlocks were predominantly used to attach to gates – preventing trespassing.

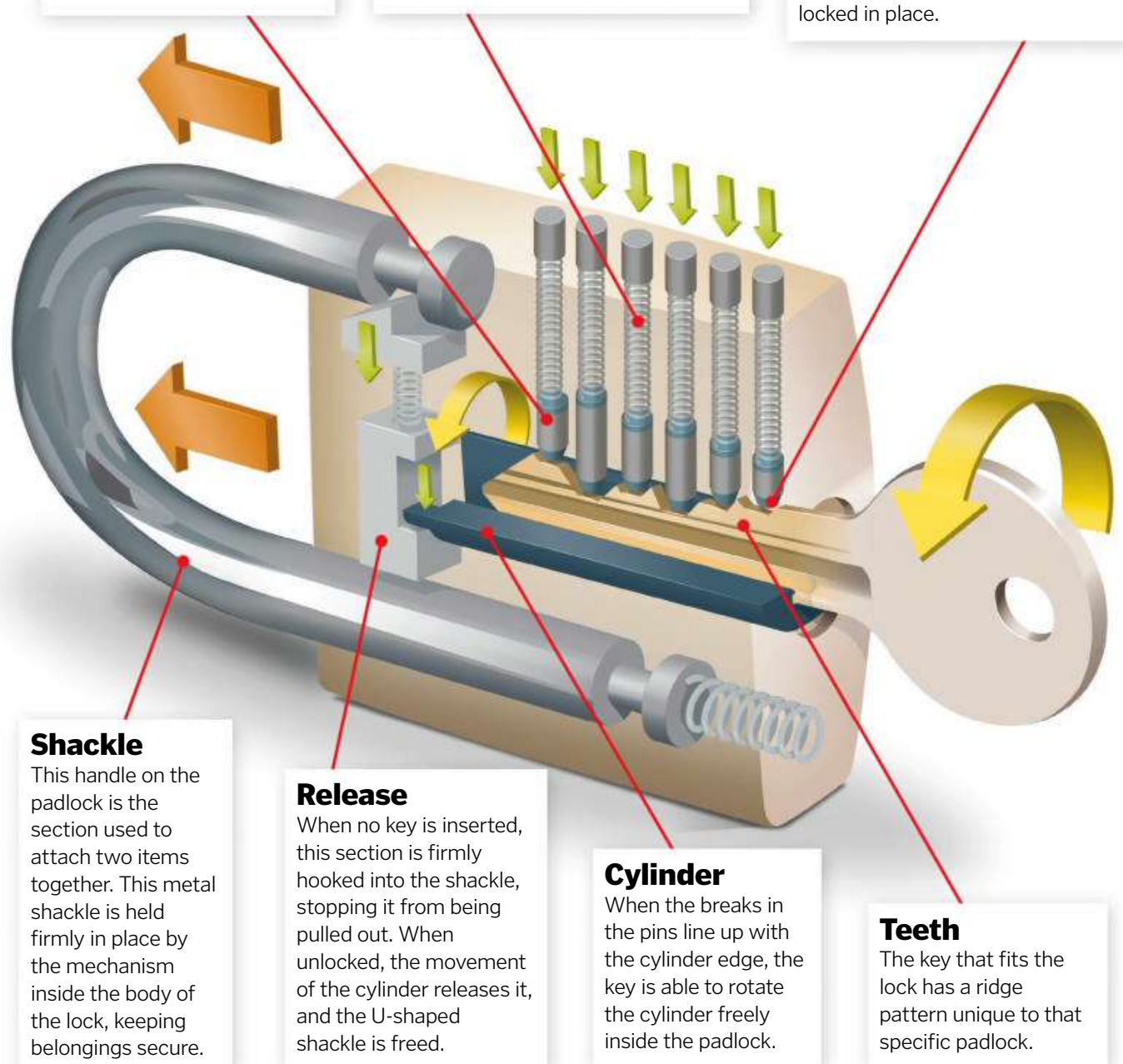
This security is very important, as we often become emotionally attached to our belongings, even if it's not something high in financial value. Whether we need to secure our bikes up outside or keep our clothes and valuables contained in a locker at the gym, padlocks ensure we don't have to keep a constant eye on our possessions and keeps them safe from being stolen.

Padlocks unlocked

How the unique pattern on a key causes the tumblers to turn within

The average padlock on this 'love lock' bridge in Germany weighs 75 grams, thousands of which equal the weight of 400 people

© Getty


Pin height
Each pin varies in height. When each of them is lined up correctly by the teeth on the key, the key can turn the cylinder without obstruction.
Spring position
When no key is compressing the springs, they relax and stretch out in their resting position. This moves the pins downwards, blocking the cylinder from turning.
Driver pins
Above the key pins are driver pins. When no key is placed in the padlock, these no longer align with the cylinder. It prevents the cylinder moving and the U-shaped shackle is locked in place.
Shackle
This handle on the padlock is the section used to attach two items together. This metal shackle is held firmly in place by the mechanism inside the body of the lock, keeping belongings secure.
Release
When no key is inserted, this section is firmly hooked into the shackle, stopping it from being pulled out. When unlocked, the movement of the cylinder releases it, and the U-shaped shackle is freed.
Cylinder
When the breaks in the pins line up with the cylinder edge, the key is able to rotate the cylinder freely inside the padlock.
Teeth
The key that fits the lock has a ridge pattern unique to that specific padlock.

© Illustration by The Art Agency/Nick Sellers

Cracking the code

Not all padlocks need keys. Combination padlocks often use a four-digit code to unlock. Inside these padlocks, four separate dials are connected to four cylindrical discs. With ten digits from zero to nine to choose from, only one of these numbers on each of the discs makes a gap within the cylinder line up in the correct place. When the correct combination is set, a series of gaps allows the shackle to slide out with no obstacles. To relock the padlock, all the numbers need to be shuffled again, keeping the lock closed.

While it would take a significant amount of time to break the code without knowledge of the correct combination, these padlocks are thought to be less secure than those using keys. However, keyless systems mean there is no possibility of losing a key and being locked out from your possessions. Taking the time to try out all possible combinations would look suspicious, but you would be able to get in eventually.

© Alamy

A four-digit combination lock has 10,000 possible combinations

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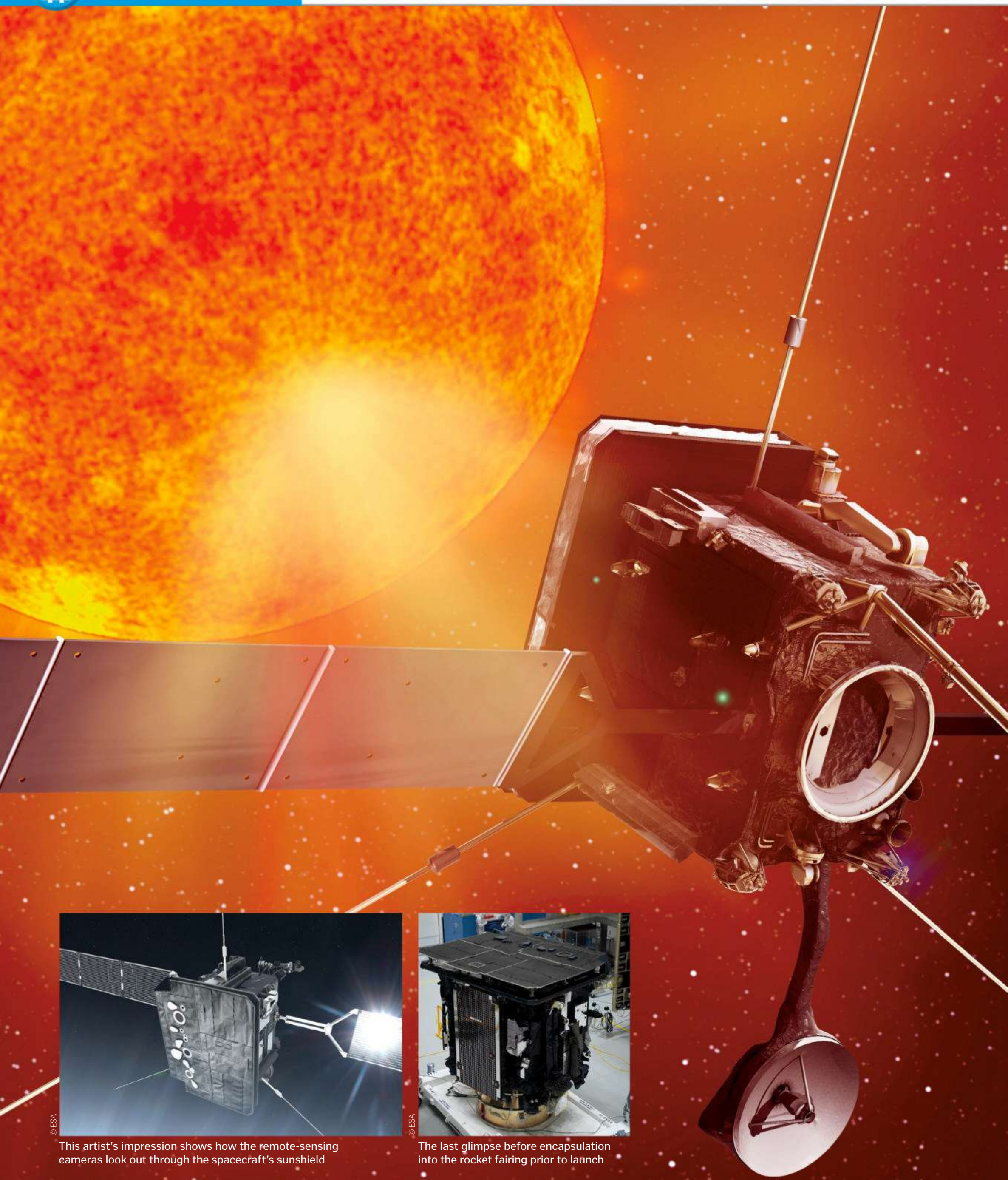

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This artist's impression shows how the remote-sensing cameras look out through the spacecraft's sunshield

© ESA

The last glimpse before encapsulation into the rocket fairing prior to launch

MISSION TO THE SUN

The Solar Orbiter will take a close look at the Sun to unlock secrets of the Solar System

Words by **Andrew May**

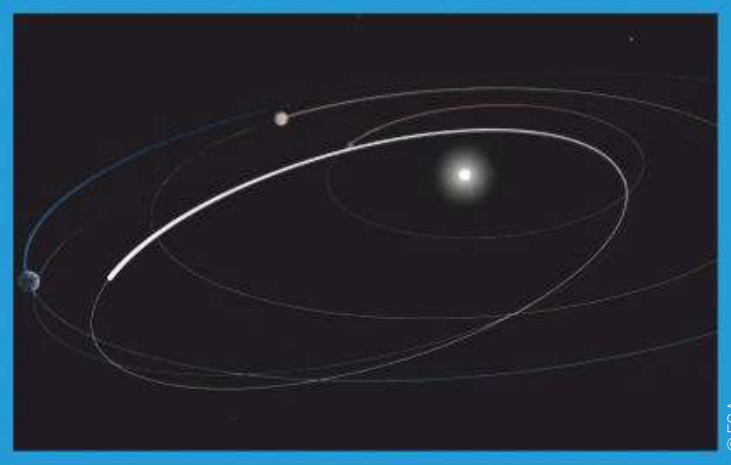
The European Space Agency (ESA) usually launches its own spacecraft, but its latest mission beyond Earth hitched a ride on an American Atlas V rocket, which blasted off from Cape Canaveral in Florida on 10 February this year. Solar Orbiter, as its name suggests, will indeed orbit the Sun – but in a way that's never been done before, designed to reveal some of our star's long-held secrets.

The Sun dominates the Solar System in more ways than providing a source of heat and light. It also emits a constant stream of fast-moving charged particles known as the solar wind, which fills the Solar System with an extremely tenuous 'atmosphere' called the heliosphere. Although this is harmless most of the time, it can sometimes be the scene of extreme 'space weather' events such as solar storms. These can be hazardous to the technology we rely on – disrupting radio communication, satellite networks and, in extreme cases, even entire power grids. The primary objective of Solar Orbiter is to give scientists a better understanding of the heliosphere by getting as close as possible to its source.

To do this, Solar Orbiter is carrying more than 200 kilograms of scientific instruments – ten of them in total. These can be divided into two different – and complementary – categories.

Getting a boost from Venus

For its operational phase, starting at the end of 2021, Solar Orbiter's trajectory will be a long, looping ellipse, with an outermost extremity close to the Earth's orbit and an innermost one inside Mercury's orbit. As with most long-distance space missions, it will take advantage of the gravitational boost provided by close planetary encounters – one with Earth and two with Venus – to get to the desired orbit. That's only the starting point, though. Once there the spacecraft will use further encounters with Venus to gradually tilt its orbit relative to the plane of the planets – to at least 24 degrees and possibly as much as 33 degrees – so it has a better view of the Sun's poles.



© ESA

Solar Orbiter's trajectory (white ellipse) is tilted relative to the planets Earth, Venus and Mercury

© Alamy

When it comes to astronomical instruments, you'd normally think of a telescope, which allows you to examine an object that's a long way away. This is an example of what scientists call a 'remote-sensing' instrument, and Solar Orbiter is equipped with half a dozen such instruments to observe the surface of the Sun.

In a different category are instruments designed to make on-the-spot – or so-called 'in-situ' – measurements of the immediate environment. These are common in scientific activities such as ground-based weather forecasting, but much more of a novelty in astronomy, where the object of interest is usually a long way away. Because Solar Orbiter will fly through the inner heliosphere, however, it has a role for in-situ instruments too – there are four different types on board.

Rather than orbiting the Sun in a tight circle, Solar Orbiter will loop round in a huge ellipse, coming out as far as the Earth's orbit and diving in to inside Mercury's orbit. At its closest approach it will be little more than a quarter of Earth's distance from the Sun. It's at this point in each orbit that the remote-sensing instruments will come into play, taking the best ever high-resolution images of the Sun's surface. The probe will be moving so fast at this point that it will keep pace with the Sun's own rotation, effectively 'hovering' over the same spot on the Sun's surface for several days.

> *"Unprecedented views of the regions around the Sun's poles"*

In contrast, the in-situ instruments will be used throughout the orbit – both in the innermost, hitherto uncharted parts of the heliosphere and the more familiar regions closer to home. This will give scientists a good picture of how the solar wind evolves as it flows out from the Sun.

There's another novel twist to Solar Orbiter's mission. Through repeated close passes of the planet Venus, the orbit will gradually be tilted at a steeper and steeper angle relative to the plane of Earth's orbit. This will provide it with unprecedented views of the regions around the Sun's poles – areas that are believed to be critical to the formation of the solar wind, but are very difficult to observe from Earth.

What is the heliosphere?

Space isn't completely empty. With just a few atoms per cubic centimetre, it would count as a high vacuum in an earthbound laboratory, but in cosmic terms it's still a dynamic environment. Inside the Solar System – out to well beyond Pluto and the other distant dwarf planets – space is dominated by the solar wind: charged particles flowing out from the Sun. This creates a huge bubble – the heliosphere – enveloping the whole Solar System.

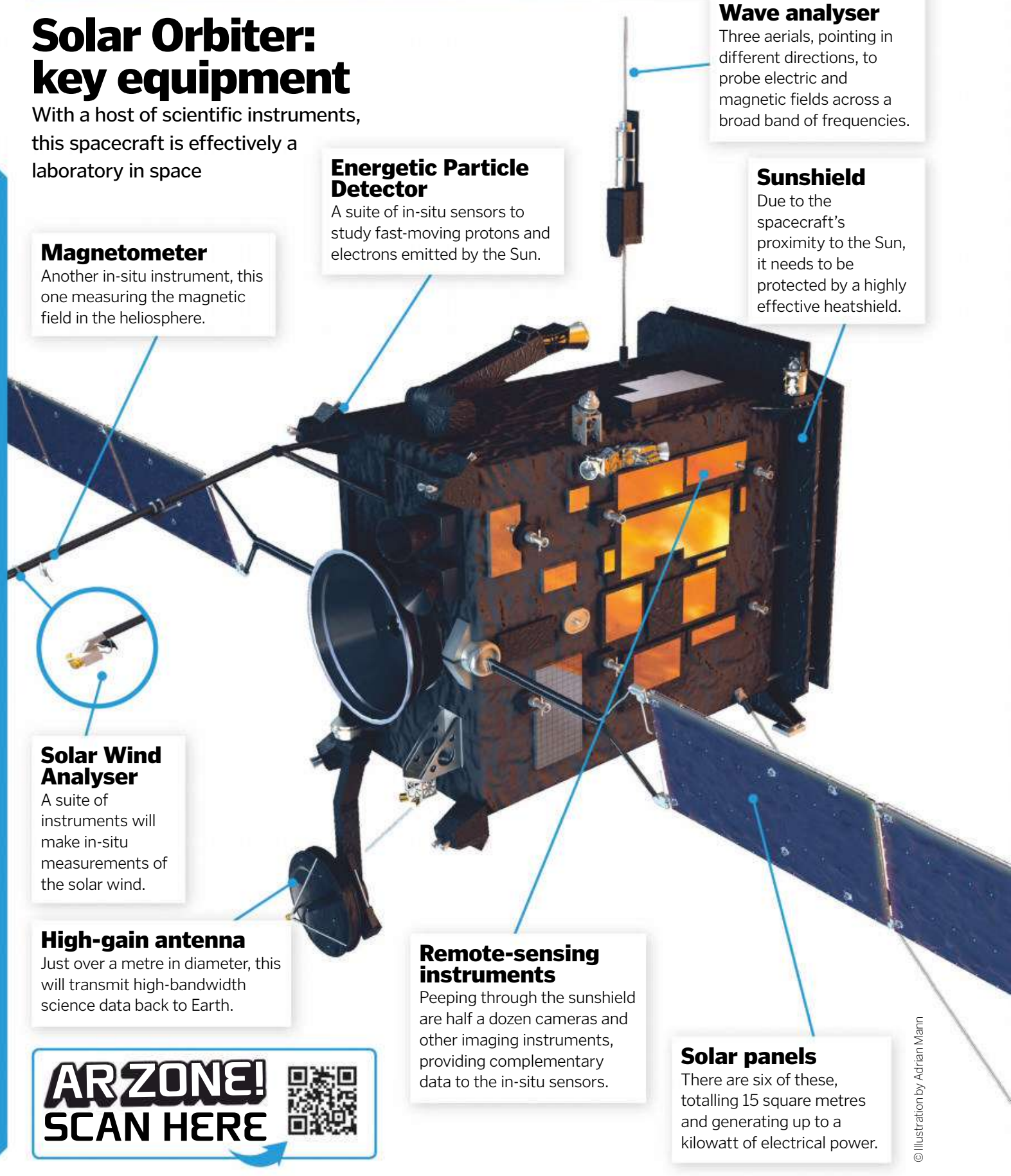
Instead of a true sphere, the heliosphere is blown into an elongated shape, like a wind sock, by the Solar System's motion through the surrounding interstellar medium, which even creates a 'bow wave', like a ship. The point where the heliosphere's density drops to that of the surroundings is called the 'heliopause'. But even before this the outflowing material finds itself battling against the interstellar medium – the place where this effect starts is called the 'termination shock'.

© NASA

Schematic illustration of the heliosphere and its interaction with the interstellar medium

Solar Orbiter: key equipment

With a host of scientific instruments, this spacecraft is effectively a laboratory in space



Radio and Plasma Wave analyser
Three aerials, pointing in different directions, to probe electric and magnetic fields across a broad band of frequencies.

Energetic Particle Detector
A suite of in-situ sensors to study fast-moving protons and electrons emitted by the Sun.

Sunshield
Due to the spacecraft's proximity to the Sun, it needs to be protected by a highly effective heatshield.

Magnetometer
Another in-situ instrument, this one measuring the magnetic field in the heliosphere.

Solar Wind Analyser
A suite of instruments will make in-situ measurements of the solar wind.

High-gain antenna
Just over a metre in diameter, this will transmit high-bandwidth science data back to Earth.

Remote-sensing instruments
Peeping through the sunshield are half a dozen cameras and other imaging instruments, providing complementary data to the in-situ sensors.

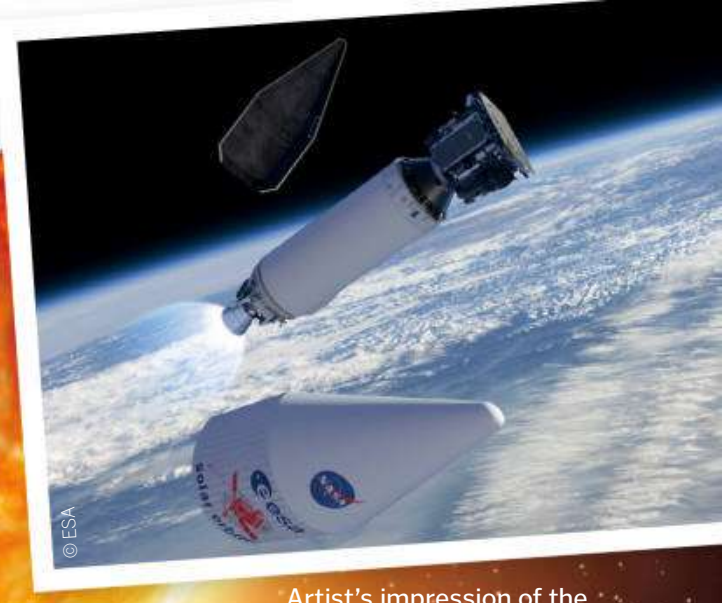
Solar panels
There are six of these, totalling 15 square metres and generating up to a kilowatt of electrical power.

© Illustration by Adrian Mann

AR ZONE! SCAN HERE

DID YOU KNOW? *Spacecraft Voyager 1 and 2 have ventured past the heliosphere*

TIMELINE OF KEY SOLAR SCIENCE MISSIONS



Artist's impression of the spacecraft being released from the fairing after launch

2018
Parker Solar Probe (US): A complementary mission to Solar Orbiter, it's smaller but will orbit even closer to the Sun.

Parker has already broken Helios-B's record, and isn't at its closest to the Sun yet

2010
PICARD (France): Observing the Sun from Earth orbit, it's named after 17th-century astronomer Jean Picard, not the *Star Trek* character.

1995
Solar and Heliospheric Observatory (Europe/US): Still active today, SOHO sits at the stable Lagrangian point between Earth and the Sun.

Ulysses needed a gravitational boost from Jupiter to put it in the desired orbit

1990
Ulysses (US/Europe): Like Solar Orbiter, this followed a high-inclination orbit around the Sun to get a view of its poles.

Genesis had a bumpy but survivable landing on its return to Earth

2001
Genesis (US): An ambitious and largely successful mission to collect solar wind particles and return them to Earth.

1991
Yohkoh (Japan): Located in Earth orbit, this satellite was designed to observe high-energy X-rays emitted by the Sun.

OSO 1 was the ancestor of Hubble and all other space telescopes

1962
Orbiting Solar Observatory 1 (US): The first telescope ever launched into orbit, it was specifically designed to study the Sun.

1976
Helios-B (Germany/US): The first spacecraft to fly inside Mercury's orbit; no spacecraft got closer to the Sun until 2018.

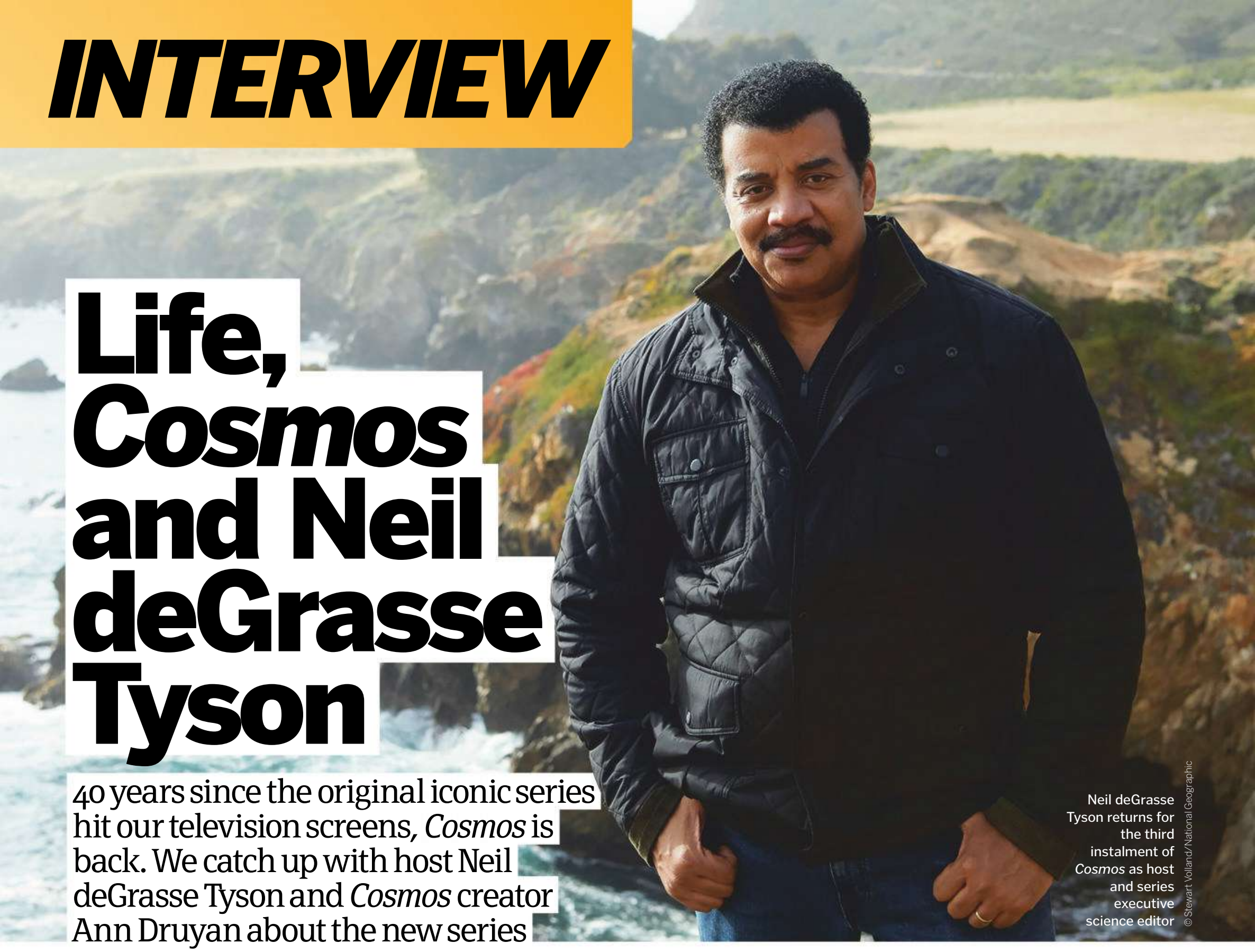
The faulty SolarMax satellite, photographed by the Shuttle crew before they repaired it

1980
SolarMax (US): An Earth-orbiting solar observatory, it made headlines in 1984 when it was repaired in space by Space Shuttle astronauts.

1965
Pioneer 6 (US): The first spacecraft to focus on studying the heliosphere did so from an orbit between Earth and Venus.

INTERVIEW

Life, *Cosmos* and Neil deGrasse Tyson



Neil deGrasse Tyson returns for the third instalment of *Cosmos* as host and series executive science editor

© Stewart Volland/National Geographic

40 years since the original iconic series hit our television screens, *Cosmos* is back. We catch up with host Neil deGrasse Tyson and *Cosmos* creator Ann Druyan about the new series

Astrophysicist Neil deGrasse Tyson is the host of the Emmy-nominated *StarTalk*, a best-selling author and science communicator. Following in the footsteps of revered astrophysicist Carl Sagan, who pioneered the groundbreaking 1980 space documentary series *Cosmos*, Tyson takes audiences through the interconnectivity of our universe and life on Earth in a new and visually stunning 13-part series: *Cosmos: Possible Worlds*.

Is it true that we are all made of stardust?

One of the remarkable things about the universe is that the laws of physics that we measure here on Earth apply everywhere. This was not a given when we first started thinking about the universe as a place where laws apply. It not only applies on Earth, but on other planets, stars in other galaxies, and it applies throughout all time. As we look at outer space, we look back in time, and as we see things in the past, the laws of physics are manifesting in exactly the way they manifest in the present. Then we can ask, what are we made of? We're made of these organic molecules containing atoms: carbon, nitrogen and oxygen and silicon. But where do these come from? I remember asking my chemistry teacher in high school where they came from, and she said "they're in the Earth", and that wasn't satisfying enough to me. Then I studied more astrophysics, and learnt the origins of these elements are traceable to stars which manufacture these elements. These elements that we are comprised of are the most common elements in the universe. How innovative it is for the universe to take its most common ingredients and make something that can contemplate its own existence, which is what happened in at least one place in the universe, here on Earth. The notion that we are stardust is not only poetically accurate, but it's actually literally true.

How have scientific discoveries made since 1980 influenced the new series?

That's a great question because there are different ways I can splice it. I can splice it scientifically, but also culturally. *Cosmos* is a source of intellectual and cultural enlightenment. By the time you're done watching it, you feel empowered by what you've just learned to do something about the civilisation in which we're all embedded. From 1980, I can list all the scientific advances since then, but it's not what matters as much to *Cosmos*. In 1980 we were still in the Cold War. There are some aspects of that program, given the idiocy of the world being held hostage by nuclear weapons. Right now we're not in a Cold

© National Geographic

Cosmos ventures from the dawn of the universe to possible worlds yet to be discovered

Neil takes the audience on a journey through Earth's history to better understand the world we live in today

© National Geographic

Throughout the series Neil explores the possibilities of future technologies for survival

© National Geographic

War, but we have other challenges. Back then, while scientists knew we were warming the planet, it was not yet public… the public had not really latched on to that reality. But of course, climate change has become an emerging existential threat that has occupied much of the attention of this third instalment of *Cosmos*. We talk about discoveries such as black holes in the centres of galaxies and exoplanets, but at the end of the day, *Cosmos* takes these discoveries and holds them up to you and says, given these discoveries, and newfound understanding, what is our place in the world and in the universe, and what are we going to do about our fate?

What surprised you the most during the making of *Cosmos*?

My expertise is astrophysics, but one of the fundamental elements of *Cosmos*' DNA is the seamless blending of the branches of science. One of the great strengths of *Cosmos* is how nimble the narrative is in weaving through these different subjects. Some are quite challenging. Quantum physics is a topic, and there's an episode where we go inside the atom. There were some challenges that I think we rose to. We have very creative people – set designers, visualisers – and they're guided by the science and rose to that challenge. All of these become parts of the storytelling and the concept of *Possible Worlds*, even though the context is the universe because that's your first thought.

You will learn in the series that a world doesn't have to be a body in space. There's this mycelium, an interconnected network underfoot which plants use to communicate with one another electrochemically. That's a world. There's an episode on the first occasion where brain waves were measured and the birth of neuroscience. Talk about a frontier. That's a whole universe unto itself. *Possible Worlds* breaks our own ego and our own stereotype of what we think the world is. Our ego, in the sense that we think we're the only ones communicating and who have a network of the internet, but the mycelium network predates the internet. It's a way to achieve a new perspective on ourselves. *Cosmos: Possible Worlds* shows you worlds that were hidden in plain sight, as well as worlds in space.

COSMOS: POSSIBLE WORLDS is available to watch now on *National Geographic*

What lesson can viewers learn from the show?

That science is an awesomely powerful tool to benefit us, but you don't want it to benefit us in a way that disrupts the ecosystem that sustains us. It's using wisdom and knowledge in the service of not only our own happiness and survival for the future, but as a way to thrive, and how do we without destroying the very thing that supports us in the first place? That takes inventive engineering and science. All of that is captured if not in one episode then in another across the season of *Cosmos*. It's not preachy, but it's there. Definitely, you come away wanting to become a participant in the solution, not simply an observer of it.

The notion that we are stardust is not only poetically accurate, but it's actually true

Druyan won the prestigious Emmy and Peabody awards for *Cosmos*

© Stewart Volland/National Geographic

Ann Druyan

Did you collaborate with other academics while writing *Cosmos*?

I had a vision for what season three would be. I had been collecting stories, but then I sat down in a room with my collaborator, Brannon Braga, and we sat there for at least a year and picked the brains of a dozen leading scientists in their field and asked them, without any shame, the most basic questions, because that was the only way that we could really understand. Once we had talked to them, we would sit alone together, the two of us, and that's how the episodes were written, informed by science.

***Cosmos* not only informs, but entertains – is one of these more important than the other?**

You need both; that's how a story qualifies for inclusion in *Cosmos*. It has to be a way into understanding the science, whatever scientific concept we're trying to communicate, but it also has to make your heart pound. We're a story-driven species.

How did you tackle the huge amount of visual effects?

This was a chance to do something that conceivably could make a difference, and Brannon Braga and I together have some crazy dreams. There are a couple of thousand visual effect shots in these 13 hours as the result of some 35 to 50 iterations where Brannon and I sit in this screening room and look at each shot, and sometimes it took 50 or 60 times to get the shot right. But I think I can speak for Brannon and say that we were both thrilled with the result. It has exceeded our wildest expectations.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?

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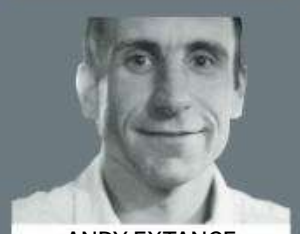
MARK SMITH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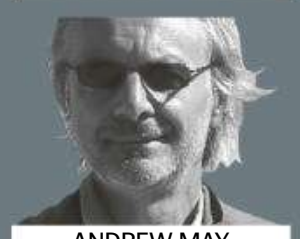
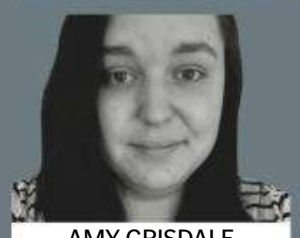

ANDREW MAY


AMY GRISDALE

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Why is it warmer just before sunrise than just after?

Lukas Weiss

The temperature drops overnight because Earth loses its heat to space. Just after the Sun rises, when its rays are coming at a low angle through a lot of atmosphere, it doesn't produce enough heat to counterbalance this loss to space, so temperatures continue to drop. **AM**

© Getty

Is it true that we can't sneeze with our eyes open?

Phil Rhodes

It's not impossible to keep your eyes open when sneezing, and they certainly won't pop out of your head if you do. A sneeze engages muscles in the chest, throat and face, and these contract automatically. Our eyes closing is part of that reflex, but it can be overridden by force – though we don't recommend trying it. **AG**

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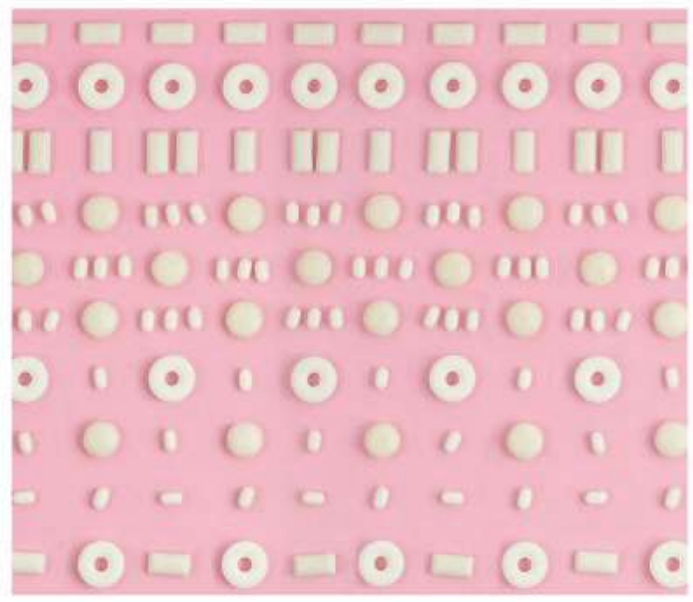

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Why do some mints have beef gelatin in them?

Lisa Carter

Food makers use gelatin in many of their products, including mints, as a stabiliser. It stops all the ingredients mixing together and making the mints separate while they're in storage. **AE**

What makes salt bad for you?

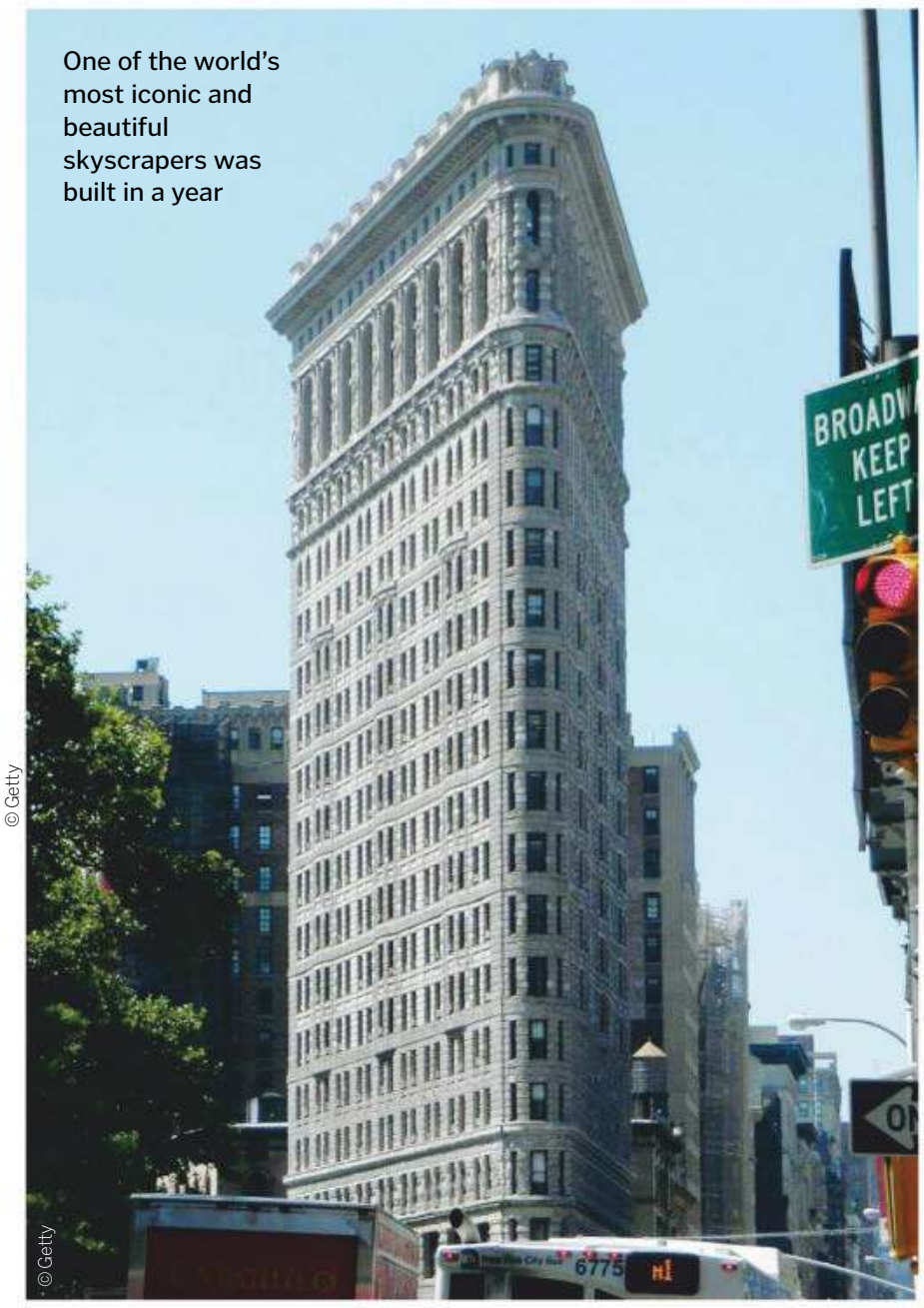
Brenda Dean

Actually, we need to eat salt – it helps our cells to send messages to each other, for example. Eat too little and you would feel tired and weak. But too much puts you at risk of heart attacks. Our kidneys filter out excess salt, but they can get worn out. When this happens the body absorbs more water to dilute the saltiness in our blood. The extra liquid strains the heart and blood vessels, wearing them out. **AE**

© Getty

It's important to eat some salt, but not too much

One of the world's most iconic and beautiful skyscrapers was built in a year



© Getty

How was New York's 'Flatiron Building' built?

Valeria Palazzo

Originally the Fuller Building, the iconic Flatiron Building in New York was built in 1902 having been designed by architect Daniel Burnham. Although it isn't overly tall, standing at a mere 22 stories, the wedge shape of this unusual building has ensured that it is one of the most photographed structures in the city. Constructed to fit into a triangular piece of land between Fifth Avenue and Broadway, the Flatiron was built directly on the street under a steel frame rather than on a typical block base, giving it the look of a fragile, freestanding tower, clad in limestone and terra-cotta. **JE**

BRAIN DUMP

Will cities ever be car-free?

Zara McLean

Private vehicles are our preferred method of travel, so it's hard to imagine life without them. There are already urban areas across the world where cars are not allowed. Oslo and Madrid are two of the latest cities to eliminate car travel to cut down on both air pollution and traffic accidents.

The process begins with establishing car-free zones, which are expanded gradually. The most important thing is to provide reliable alternative modes of travel. Cities around the world need to improve public transport and encourage green ways of getting around, like walking and cycling. **AG**

Hamburg is developing a 'green network' that links car-free streets with parks and public footpaths

Is a coconut a nut?

Rajesh Jayaraman

A coconut is actually a one-seeded drupe, which is a fruit with a stone in the middle containing seeds. Drupes include olives and apricots as well as the coconut. They are not nuts because a coconut seed germinates and sprouts out of the shell, while a true nut will not split open when ripe. The white flesh that we love to eat is part of the coconut seed and not the fruit as many believe. **JE**

The coconut has three layers: a fruit, a stone and a seed

Did Caesar really wear a laurel wreath on his head?

Eugene Fox

Laurel wreaths, known as the Corona Civica, were worn as a sign of victory in battle and were used on special occasions rather than for everyday attire. Caesar was awarded his for fighting in Asia Minor. It is said that he wore his more frequently because he was going bald. **JE**

The Einstein Cross, a multiply imaged quasar thanks to a much closer gravitational lens

What's a gravitational lens and where's the nearest one to us?

Mayu Hayashi

Gravitational lensing is the bending of light around an object by its gravity. Any very massive object, such as a galaxy, has the potential to be a gravitational lens, but we only perceive it as such if there is another even more distant – and very bright – object along the same line of sight. In this situation we may see multiple images of the distant object, such as the 'Einstein Cross' – a quasar at the incredible distance of 8 billion light years. The lens in this case is a 'mere' 400 million light years away – the closest currently known. **AM**

Countries like France require driving licenses, but not every country does

Do all countries require road users to have driving licenses?

Jeffrey Weaver

In some countries a driving license is a legal requirement, while in others it's not obligatory. However, car rental firms, for example, will often still insist on one if a tourist wants to drive in that country. A British motorist's ability to drive in Europe is usually pretty unrestricted as long as they have a UK license – though Brexit is most likely going to change this. In some countries though you might need what's called an IDP, or International Driving Permit. There are three different types of IDPs: the 1926, 1949 and 1968 Convention IDP, and depending on which countries someone visits – or drives through – determines which IDPs are needed. **MS**

What is a firewall?

Russell Ryan

A firewall is a barrier that keeps an eye on data coming in and out of a computer system, but it only lets data in if it fulfils specific rules. A firewall can be hardware, software or both, and has been a cornerstone of computer defence for decades. **MS**

© Image by Pete Linforth from Pixabay

© Image by Ryzom

What makes an MMORPG different from other video game types?

Emma Coleman

The biggest difference is size. They feature open gaming worlds and huge numbers of online players. The gaming world continues to exist and evolve even when you're not playing it. **MS**

German Autobahnen were designed for virtually unrestricted travelling speeds

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Why do Germany's motorways have no speed limit?

Victoria Watkins

Germany is the only country in Europe with no speed limit on vast stretches of its highways. German motorways – known as Autobahnen – are wider than UK motorways and were designed to let motorists get from A to B as quickly as possible – hence no need for speed limits. However, some restrictions do exist near towns, cities and ongoing roadworks. Not having a speed limit is also considered a point of cultural and national pride for German drivers. **MS**

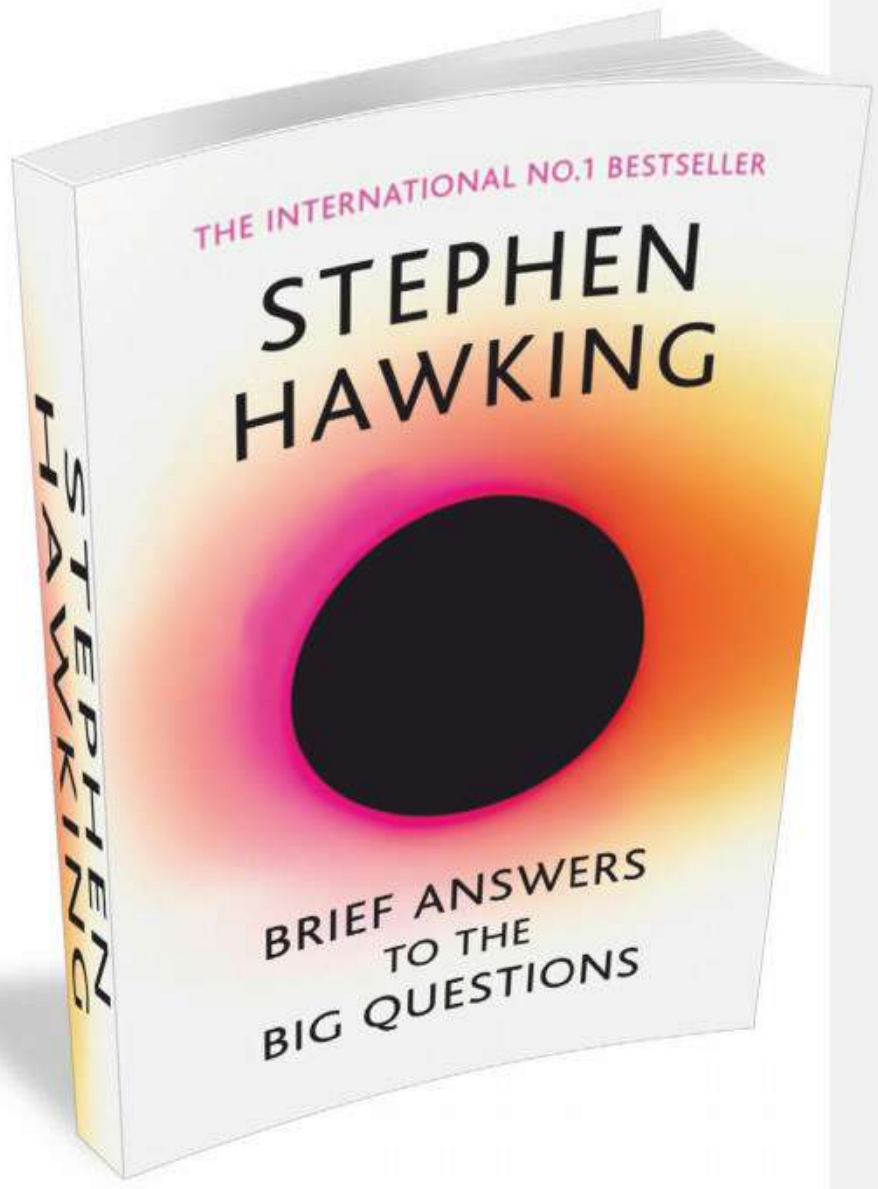
BOOK REVIEWS

The latest releases for curious minds

Brief Answers to the Big Questions

The final book from one of the world's greatest scientists

- Author: **Stephen Hawking**
- Publisher: **John Murray**
- Price: **£14.99 / $21.75**
- Release: **Out now**



Few minds have had such an impact on the way we think about the cosmos as Stephen Hawking. His theories about the origins of our universe and the nature of black holes have changed the scientific community, and 1988's *A Brief History of Time* introduced Hawking to a wider, more mainstream audience. In turn he's appeared in all kinds of pop culture, from *Star Trek* to *The Big Bang Theory* and *The Simpsons*.

It's been more than two years since Hawking passed away at the age of 76. *Brief Answers to the Big Questions* is his final work – his last chance to address questions like 'Is there a God?' and 'Is time travel possible?'.

The book is the result of Hawking revisiting his personal archive of memoirs, lectures and writing in his final years. He died before completing the book, but it was so close to being finished that his colleagues, friends and family could pull together the loose ends and create a book that isn't just a compilation of material we've seen before. It feels fresh and new – a truly fitting way to say goodbye to the greatest mind of a generation.

Hawking begins with a brief history of his life, from his earliest days of childhood to the modern day. It's a whistle-stop tour, but does a fantastic job of setting the scene for his accomplishments later in life. From there, Hawking's entertaining, informative writing style carries us through all kinds of serious questions with engaging, often witty explanations that are incredibly accessible – even to those without much scientific knowledge. It's already sold almost 2 million copies worldwide, and that number is sure to increase – this is the perfect way to celebrate the life of one of the greatest scientists and most inspirational people ever to have lived. He ends his book with a message that bears repeating here.

A truly fitting way to say goodbye to the greatest mind of a generation

"Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don't give up. Unleash your imagination. Shape the future."

★★★★★

The Secret Life of the Periodic Table

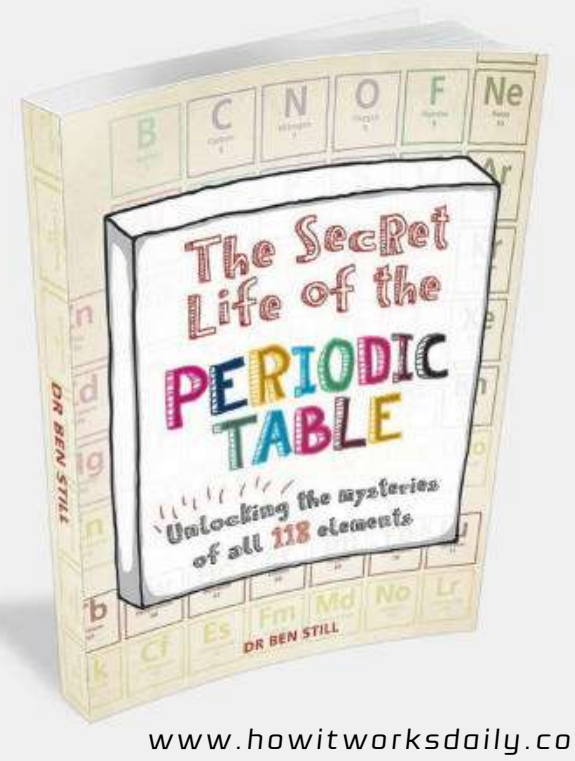
Elements of excellence

- Author: **Dr Ben Still**
- Publisher: **Cassell**
- Price: **£12.99 / $24.99**
- Release: **Out now**

The chances are that you know at least some elements – perhaps you can recite the majority of the periodic table. But how much do you actually know about them? Do you know how they are used, or how they were discovered? To aid us in our understanding, the book begins with the earth, air, fire and water postulations of Aristotle before moving onto Dmitri Mendeleev's serious construction and refinement of the periodic table. From there we get a rundown of the table's components, from hydrogen all the way through to ununoctium – not to mention ponderings on the possibility of discovering all-new elements.

Did you know that hafnium is used in nuclear reactors? Or that bismuth was initially used to create knives? This is just a small sample of the wealth of information stored within these pages. Each page is accompanied by illustrations and vital facts and figures to keep things interesting, and despite the section-orientated format, it never feels repetitive. Beyond an introduction to the periodic table, this is handy for anyone looking to brush up on their knowledge or discover new things.

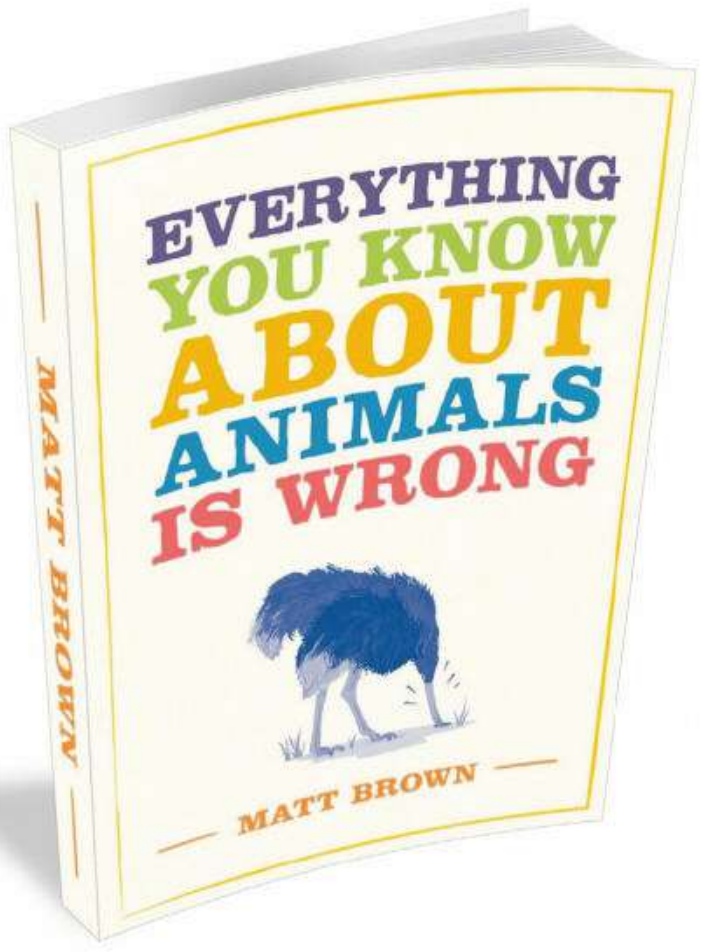
★★★★★



Everything You Know About Animals Is Wrong

Correcting myths about mammals

- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 / $12.95**
- Release: **Out now**



Space, science, London, planet Earth – if it exists, chances are that Matt Brown has pulled you up on it at some point. It's the name of his signature book series, after all. This time, it's the turn of the animal kingdom to have its world put to rights as Brown goes about debunking various myths and filling in the subsequent blanks.

Camels storing water in their humps? False. Ostriches bury their heads in sand as a matter of course? Also false. You can get warts from picking up toads? No truth in that one whatsoever. You get the basic picture.

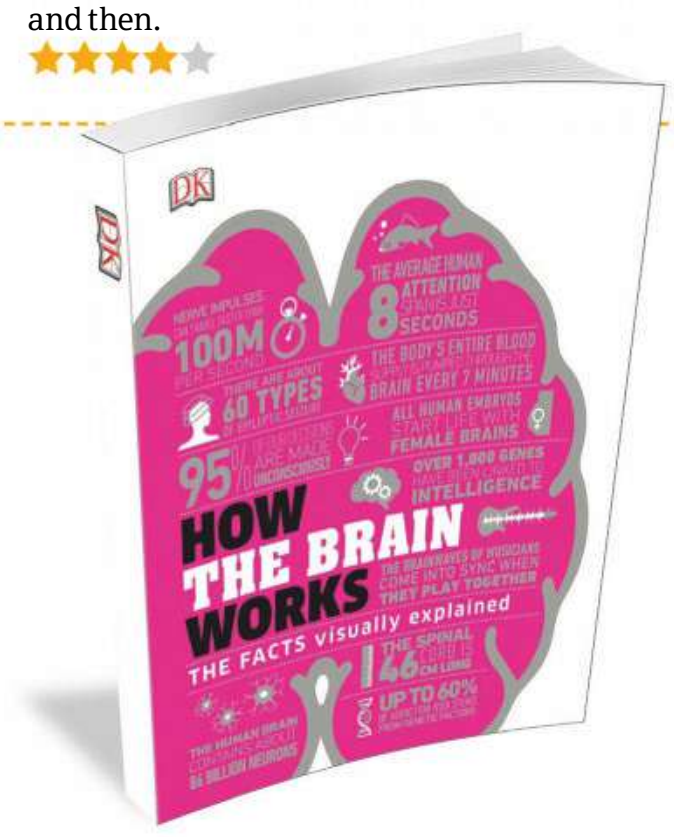
While lighthearted in tone, a lot of knowledge is nonetheless imparted, and Brown's natural wit and obviously in-depth levels of research shine through. It's not likely to be the kind of book you'll finish in one sitting, but is likely appealing to dip in and out of every now and then.

★★★★☆

How The Brain Works

Intel on your little grey cells

- Author: **DK**
- Publisher: **Dorling Kindersley**
- Price: **£16.99 / $22**
- Release: **Out now**

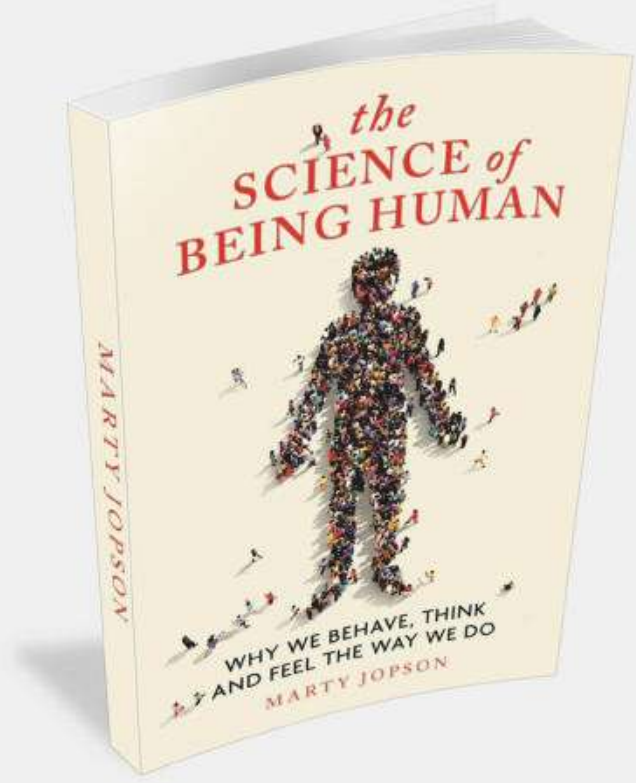


No one needs telling that the brain is a complex part of the body, which makes it a good thing that we have Dorling Kindersley on hand to break down the inner workings of this most complex of body parts in what has become its trademark fashion. By this, of course, we mean the use of infographics, boxouts and concise yet informative language to break things down to size.

With seven primary sections – the physical brain, functions and senses, communication, memory, consciousness, the future and disorders – everything is divided clearly in a manner that makes them easy to locate. And when you get there, you are greeted by the highest quality diagrams that aid in your understanding of the subject. It's still not by any means easy considering the sheer complexity of the subject matter, but it definitely adds to the enjoyment factor.

We can't emphasise how much of a valuable resource this is. In an age where it's easy to be overwhelmed by the sheer quantity of information out there, it's almost a relief to have something like this at hand: relatively brief in terms of what's contained within, but informed by the highest levels of production quality and research.

★★★★★



The Science of Being Human

What next for us?

- Author: **Marty Jopson**
- Publisher: **Michael O'Mara**
- Price: **£12.99 / $19.95**
- Release: **Out now**

Traditionally the study of how our body works has overshadowed any ponderings on why we are the way we are, and what factors influence our behaviour. Writer and presenter Marty Jopson attempts to redress the balance in this book, delving into topics like maths, science, psychology and philosophy in his customary inquisitive style.

Timely topics include our behaviour on the internet and the art of lying, and much more besides. It's hard to do justice to just how intriguing this subject is. Over the years, a secret evolution has been going on in our minds, and this book is one of the first times we've seen this encapsulated in book form.

This has the capacity to be one of the most important books you'll ever read – we're certainly having these kinds of feelings ourselves. We advise that you don't delay; go out and pick up a copy right now.

★★★★★

A secret evolution has been going on in our minds

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 What's the name of your thigh bone?
- Fibula
- Femur
- Scapula
- Tibia

Q2 What was the Greek god Atlas known for?
- Being lord of the ocean
- Ferrying the dead
- Pushing a boulder
- Holding the sky up

Q3 Which pandemic was the deadliest?
- Plague of Justinian (541-542 CE)
- The Black Death (1346-1353)
- Third Cholera pandemic (1846-1860)
- The Spanish flu (1918-1920)

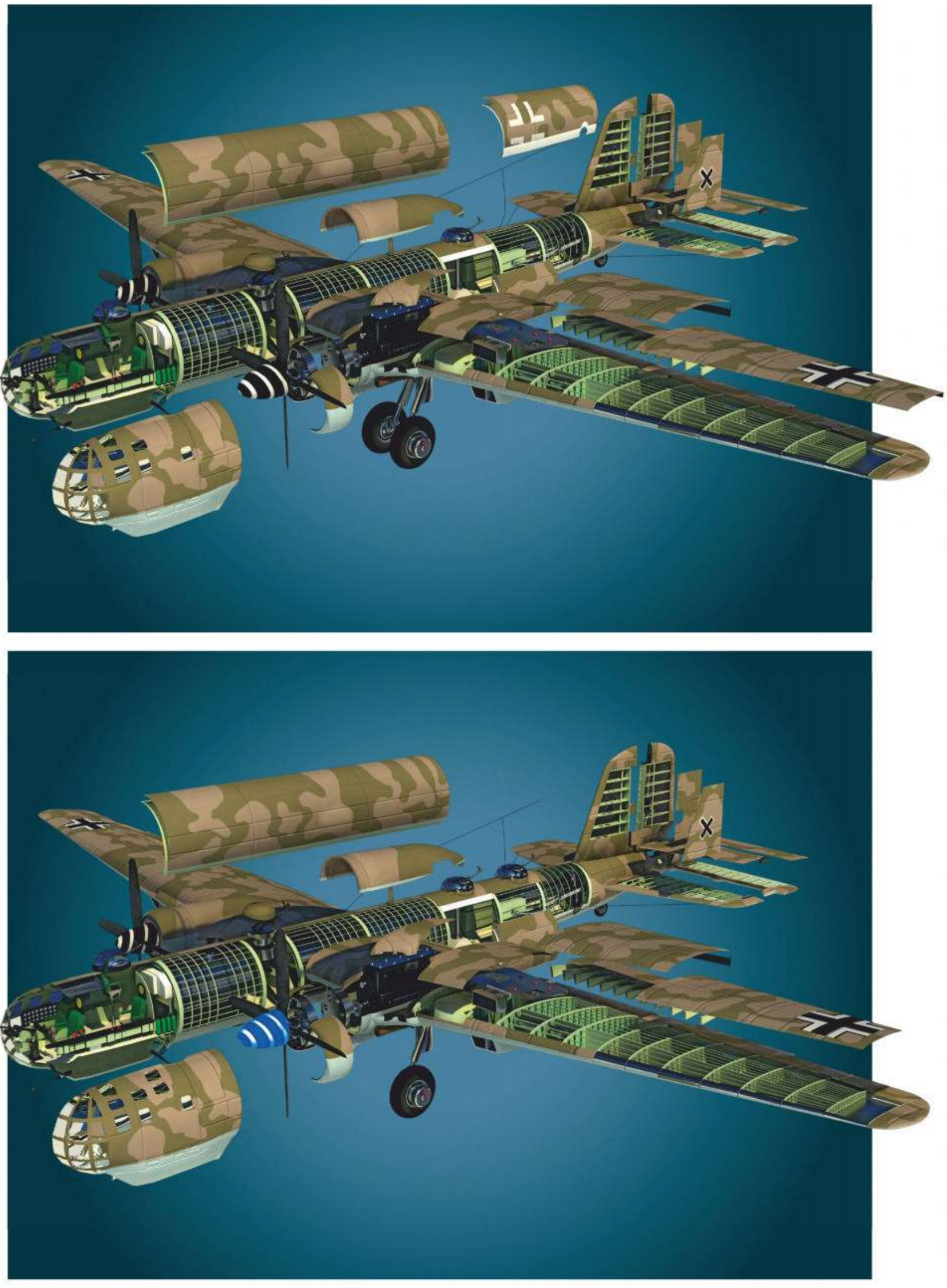
Q4 Which of these is the 'love hormone'
- Testosterone
- Progesterone
- Oxytocin
- Insulin

Q5 What temperature will Solar Orbiter face?
- -273.15 degrees Celsius
- -50 degrees Celsius
- 500 degrees Celsius
- 5,000 degrees Celsius

Q6 How high is Olympus Mons on Mars?
- 8,848 metres
- 15,397 metres
- 21,287 metres
- 28,848 metres

Spot the difference

See if you can find all six changes between the images below



Sudoku

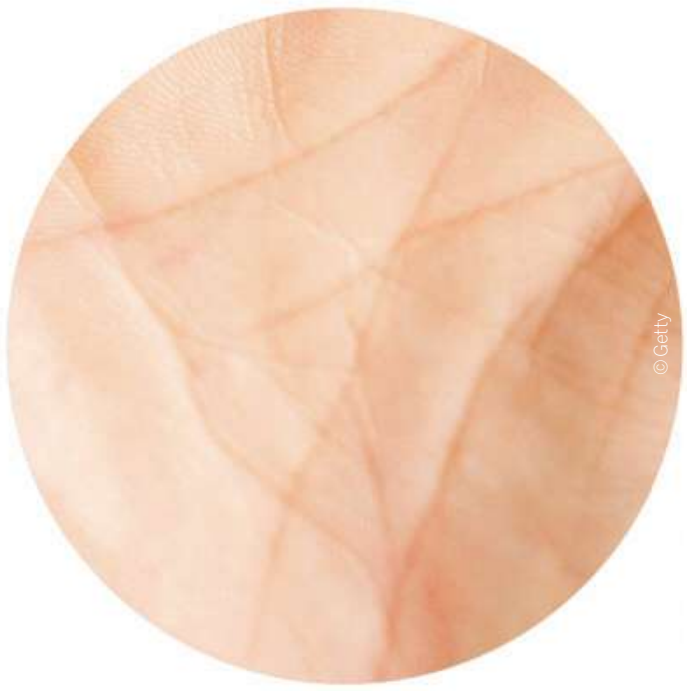
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	2	9	3		6			
	7			4	9	3		6
4			2	5	8		9	
9		2	7	8	3		6	1
6		5	4		1	7		2
8				2		4	3	9
		1	8					
7						2		
3	8		9				7	

DIFFICULT

		6						3
2	1					6		
5		8			2			
		5			3			
3				9	4			7
6	7				5		1	
		4					3	
		1	5				2	
		3	7	4				



© Getty

What is it?

Hint: A fortune teller might read this…

A .....

G	L	O	V	A	W	T	S	N	P	I	O	L	E	H
H	Q	B	L	E	L	A	C	T	I	C	Z	E	X	O
C	I	O	P	H	J	C	E	T	Y	I	N	D	M	R
O	N	M	F	Z	N	U	C	C	I	H	T	I	P	M
M	N	U	A	T	Y	L	M	P	E	L	E	L	T	O
A	E	L	R	L	I	W	R	X	E	M	R	G	A	N
R	V	B	O	R	A	N	O	N	K	L	P	J	O	E
E	K	U	E	D	L	Y	R	O	V	A	L	C	K	F
F	C	H	I	E	N	T	A	T	O	R	L	E	B	A
J	O	M	O	Y	X	V	A	S	N	J	P	B	T	O
C	L	U	M	T	Y	P	H	O	I	D	V	I	X	B
S	R	D	J	C	A	H	O	B	I	Y	T	F	A	K
D	E	W	A	E	A	A	X	R	S	U	L	I	P	V
S	E	S	O	L	A	R	I	O	A	Y	I	M	O	T
G	J	A	S	N	I	F	P	S	A	G	A	N	N	Y

Wordsearch

FIND THE FOLLOWING WORDS...

QIN
HIMALAYAS
FLY
SOLAR
HORMONE
BOSTON
LOCK
LACTIC
PELLET
SAGAN
TYPHOID
GLIDE

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 A malicious computer program
Q2 Carbon monoxide
Q3 20,000 tons of TNT
Q4 They pollinate plants
Q5 275mph
Q6 A satellite

WHAT IS IT?...GOLF BALL

© Getty

WIN! A PAIR OF DISNEY TABLETS

This month we are giving you the chance to win a *Frozen II* and *Toy Story 4* kids' tablet by Pebble Gear. Each tablet is equipped with full parental control and access to over 500 games and apps.

WORTH OVER £199

For your chance to win, answer the following question:

Which of the following is NOT a bone in the leg?

a) **Femur** b) **Clavicle** c) **Tibia**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 7 May 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: www.futuretcs.com. Entries must be received by email or post by 00:00 BST on 07/05/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

HOW TO...

Practical projects to try at home

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

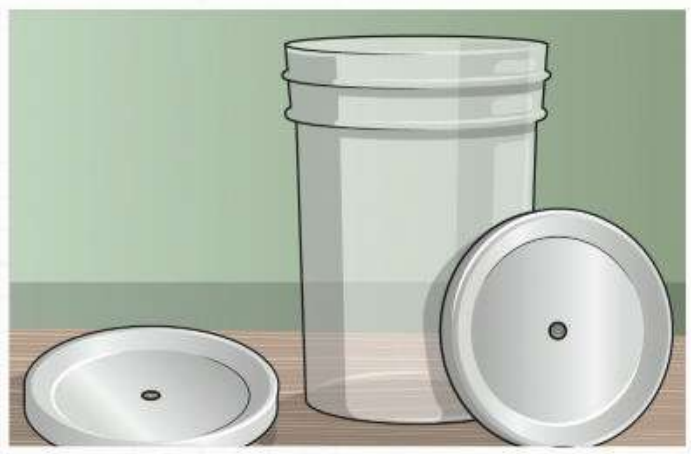
Get in touch
Send your ideas to...
How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

Make a pasta rocket

Create a fuel-powered rocket engine using a piece of pasta and some simple ingredients

1 Find a jar

You'll need a canning jar. That's a glass jar with a lid that has a separate screw section and top. We won't use the screw section to avoid pressure building up inside the jar.



2 Prepare your container

Punch a small hole through the centre of your lid, around three millimetres across – ask an adult to help. This is where the oxygen will escape through when you put the lid back on the jar.

3 Make the oxygen

Pour in hydrogen peroxide until it fills up about two-thirds of the jar. Then add a teaspoon of yeast to the jar – you should see it start to fizz, and bubbles will begin to form.

4 Bubbles of fuel

The hydrogen peroxide contains hydrogen and oxygen. The microbes in the yeast help the two elements separate, and the oxygen bubbles up. As the pressure grows, the oxygen is forced out.

5 Solid fuel

Place the lid lightly on top of the glass jar, then balance a piece of ziti pasta – like penne but with a flat, perpendicular end – on the top. The oxygen will come out of the hole and through the pasta.

6 Light up your fuel

Ask an adult to help you light the end of your pasta on fire. The oxygen coming up through the tube will burn, and the pasta acts as a solid fuel too. It will keep burning until the pasta is all black and burnt.

SUMMARY

While the oxygen fuel doesn't provide enough thrust to push the pasta downwards, this is the same concept that many large rockets use to break out of the atmosphere and into space. The complex carbohydrate in the pasta provides a good fuel that burns brightly in the presence of the oxygen from below.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
Make your own germ-killing hand sanitiser

© Illustrations by Ed Crooks

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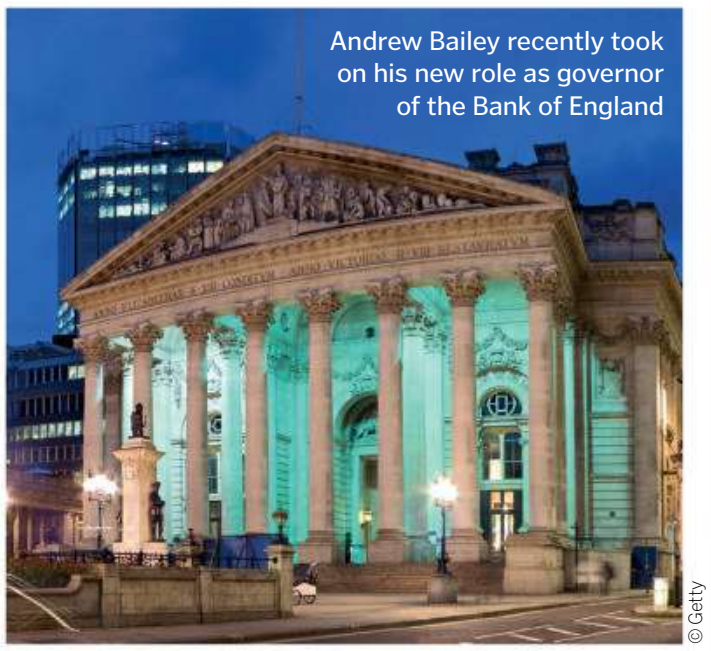
INBOX
Speak your mind...


Andrew Bailey recently took on his new role as governor of the Bank of England

© Getty

New governor

Hi **HIW,**

I'm a new subscriber to **How It Works** magazine, which I think is excellent. I'm 74 – can still learn about technology though. The article about the Bank of England is very, very interesting. The magazine was delivered to me by the postman on 14 March, and in it – on page 65 – it does say inside the Bank of England there will be a new governor from 17 March. I don't know how you knew this information before anyone else!

Kelvin Curtis

Thank you for getting in touch. We are glad that you have enjoyed your first read of How It Works and we hope you continue to enjoy learning about new technology.

In our last issue we did mention that Andrew Bailey would be the new governor of the Bank of England. While he is new to the position – recently taking on the role – the announcement of this was not so new. In December this was announced in advance and approved by the queen. Previously Bailey has been the deputy governor of the bank, as well as chief cashier. His experience made him a popular choice for this official role and will be of great use at one of the most challenging times for the bank, with the UK facing an 'economy emergency' brought on by the coronavirus.

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com

Letter of the month

Obliging bird

Hi **HIW,**

I am normally not very good at photographing quick-moving subjects like birds, but this little Bush Robin obliged me by sitting still long enough in the Sun, and I think he had an excellent sense of composition, because he has made a perfect photo.

Bush Robins are very tame. If one sits down on a track, they sometimes come up to you and hop all over you and peck at your clothing.

This photo was taken on the Lake Daniell Track near Springs Junction, New Zealand.

It was taken about ten years ago, and remains one of my favourite photos.

Best wishes,

Stephen Conn

Thank you for sharing this impressive shot with us. The clarity and focus show just how still and tame the bird must have been; we can see why it is one of your favourite photos!

Your letter highlights the difficulty many people face in achieving such a high-quality image of fast-moving animals and objects. High shutter speeds on your camera can help to 'freeze' the bird if you can keep the camera in its path. This means that even if the bird is travelling along a branch, or ruffling its feathers, you can freeze it at one point in time and reduce the blurriness of the image.

When it comes to wildlife photography, it is also important to think about how the viewer of the photo will see it. We tend to be drawn towards objects in the foreground. Keeping the focus on the bird's eye will help make the remainder of the image appear sharper. This is because people are more likely to be drawn to eyes before anything else.

© Stephen Conn

Reader Stephen Conn used patience and skill to achieve this shot

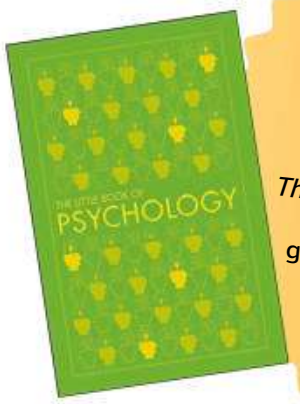
Multilingual reading

Nisa (@nsbsvx): @HowItWorksmag delisi oldugum dogrudur (true I'm crazy)

Thanks for showing us your collection of How It Works from our Turkish licensees. It's great to see our content being accessed in a variety of countries, and many languages other than English. Thanks to technology and the study of language, we are able to live in a connected world where we can share content and communicate with everybody.

A reader in Turkey shared this impressive collection with us on Twitter

© Nisa



WIN! THE LITTLE BOOK OF PSYCHOLOGY

The Little Book of Psychology by DK clearly explains over 100 groundbreaking ideas in this field of science, like how does the brain remember faces? And what makes us choose one decision over another?

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NEXT ISSUE...
Issue 138 on sale
14 MAY 2020

Stick to it

Hi **HIW,**

While cooking breakfast the other morning, I found myself without any oil in which to fry an egg. Luckily I had a non-stick frying pan my sister-in-law had gifted me at Christmas, and so I enjoyed a fried egg butty without fear of irreparably damaging any kitchenware. So my question to you is, how do non-stick pans prevent food from baking straight onto the pan, and how long have these been around?

Meryl French

© Getty

Protein-rich foods such as eggs are prone to sticking to non-PTFE frying pans

Funnily enough, the man who first discovered the resin used in non-stick frying pans actually came across it when he was researching a different kitchen appliance: the fridge. Roy Plunkett aimed to produce tetrafluoroethylene gas overnight. However, when he returned to his lab he found a white wax instead. He had actually created polytetrafluoroethylene (PTFE), which is the slippery substance that binds to the aluminium on your pan. French engineer Marc Grégoire put the two together in 1954.

The PTFE – today known as Teflon – on the pan is made of carbon and fluorine atoms. Only fluorine atoms reach the outside of this molecule, protecting the carbon atoms from reacting. In the case of your egg butty, the proteins in the egg could combine with the carbon molecules in a non-stick pan, but the fluorine prevents this from happening.

What's happening on... social media?

INSTAGRAM

Do you believe that love at first sight is possible?

62 per cent of our Instagram followers said they believed in love at first sight. Many of the remaining 38 per cent may think that a person cannot love straight away due to not knowing enough about an individual at first glance. While this is true, the first stages of falling in love can begin at first sight, and so in some ways love can start taking its course from the moment you see someone.

TWITTER

This month on Twitter we asked you: 'What is your favourite home science experiment?'

@Sparkellium
pH testing with red cabbage juice is a good one.

@grant_sheldon
Potato battery... Classic!

@dutrz
The one that pulls a boiled egg into a glass bottle

@aesthetically_aj
Making your own lava lamps with vegetable oil and food colouring

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

3.6 METRES

BEFORE THEY WERE OUTLAWED, PUNT GUNS AS LONG AS TWO TALL MEN COULD KILL DOZENS OF DUCKS IN A SINGLE SHOT

10 SECONDS

SOME THIEVES HAVE ACCESSED NEW KEYLESS-ENTRY CARS IN RECORD TIME

20 MILLION

A HUGE NUMBER OF PEOPLE STILL GET SICK FROM TYPHOID EVERY YEAR

2015

A CHEAP 'SUPER STEEL' AS STRONG AS TITANIUM WAS RECENTLY INVENTED IN SOUTH KOREA

60

SOCIAL ROBOT SOPHIA IS CAPABLE OF HUMAN CONVERSING USING DOZENS OF FACIAL EXPRESSIONS

LOVE CAN MAKE YOU FEEL LESS PAIN THROUGH THE PRODUCTION OF OXYTOCIN IN THE BRAIN

CARL SAGAN AND ANN DRUYAN DATED DURING A SINGLE PHONE CALL AND WERE ENGAGED BY THE END OF IT

10,200 METRES

EARTH'S TALLEST MOUNTAIN IS IN HAWAII: OVER HALF OF MAUNA KEA IS BELOW THE SEA

25 DAYS

ADULT HOUSE FLIES TYPICALLY LIVE FOR LESS THAN A MONTH

99.9%

MOST OF THE MASS OF THE SOLAR SYSTEM IS CONTAINED IN THE SUN

RUNNING A MARATHON DAMAGES HEART MUSCLE, WHICH HEALS COMPLETELY WITHIN A WEEK

CHINESE EMPEROR XIA JIE (1728-1675 BCE) WAS A TYRANT WHO RODE HIS ADVISORS LIKE HORSES

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INSIDE! Autumn Crafts Halloween Fu Sustainable Crafts Festive Makes Di Best Books for Autumn Cool Prizes to
65+ Springtime Crafts for Creative Kids
INSIDE! Mother's Day Easter Crafts Red Nose Day Fun Forest School Compst Recycled Crafts Painting Projects
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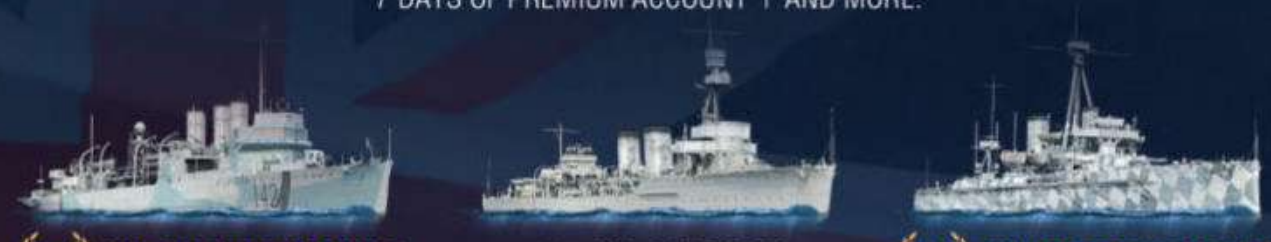

III CAMPBELTOWN | III CALEDON | III DREADNOUGHT

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